TRANSACTIONS

OF

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EDITED BY

RICHARD MOLDENKE

SECRETARY

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American Foundrymen's Association

PROCEEDINGS OF THE DETROIT CONVENTION

June 7-10, 1910

OPENING SESSION

Tuesday, June 7th, at 10 A. M., State Fair Grounds, Michigan State Building, Detroit, Michigan.

The meeting was called to order by Mr. Arthur T. Waterfall, President American Foundrymen's Association, who said:

"I take great pleasure in opening this fifteenth annual convention of the American Foundrymen's Association, the American Brass Founders' Association, the Association of Foundry Foremen, and the Foundry and Manufacturers' Supply Association.

"We have with us to-day very distinguished local guests whom the Chairman of the Reception Committee will introduce to you."

Mr. James S. Keightley, Chairman Reception Committee: "Ladies and Gentlemen, I take great pleasure in in-

troducing to you His Honor, Mayor Philip Breitmyer, who will welcome you to the city."

Mayor Breitmyer. "Mr. Chairman, Ladies and Gentlemen. I presume I meet here men who know something about the foundry business. I am sure it is a pleasant duty for me to bid you welcome to our city, and especially because you have brought with you that which makes us all happy, a bit of sunshine. I might say in that connection that my better half wakened me this morning by saying, 'We are going to have a christening.' Said I, 'What's happened; you did not tell me that last night.' Said she, 'No; I see there is a new sun out this morning.' I thought that was apropos of the occasion. (Applause.)

"I congratulate you on having secured a place like this in which to hold your conventions. I do not know that I have ever had the opportunity of witnessing a real foundry going at a convention, and I am sure that this association should be congratulated upon its success and for the many opportunities it gives to the public, to the men who are interested, as well as to give food for the thought we all require in making a success in our various businesses. The committee is fortunate to have a place like this. At nearly all the conventions that I have attended—and I happen to have the honor of being president of an association which is national in my line of business—one trouble we have always had was to hold the members' interest in the convention meetings, as they find something else to see that is almost as important as the convention. So I say, you are fortunate to have a place here away from the city life, and when you get here you can carry out your problems and the object of your meetings.

"The City of Detroit should be very grateful to you, they are under obligations to you for bringing such a convention here. The display that has been made here is certainly very instructive and affords food for thought for all of us.

"I am sure Detroit welcomes all who come in our midst. You all know about the growth of the city. It represents almost every manufacturing line under the sun; they make the small pin for a lady's use, and the great steel steamer that plies the Lakes. Detroit is glad to have you come here, and as the executive of this city it affords me much pleasure to wish you success and a hearty welcome. I am very glad to greet you on behalf of the City of Detroit."

Mr. Keightley. "It affords me pleasure to introduce to you the president of the Board of Commerce of the City of Detroit, Mr. Abner E. Larned."

Mr. Larned. "Mr. Chairman, Ladies and Gentlemen: On behalf of the Detroit Board of Commerce, an organization of 1,400 members drawn from the professional and commercial life of this city, I bid you welcome. I want to tell you that we are proud to welcome you here because you represent exactly the thing we are organized to promote—industrial Detroit. I must confess, as much as I knew of your organization, I was not prepared for the exhibition which you have on display on these grounds at the present moment; if our city knew generally that you had this magnificent 'World's Fair' out here, you would be sadly hampered in the proper function of your convention by the crowds that would attend. Possibly it is desirable to keep them somewhat in ignorance. Surely that is as interesting a showing as I have ever attended, and to me it is of very great significance.

"I recall that sometime during the last year we entertained the Japanese Ambassador and his suite. The organization of which I have the honor of being president, had their entertainment in charge. We tried very hard to give them a good time; we showed them our city, took them on our river, up to our island park, and all of our show places. But most of all they desired to see and spend most of their time in our big industrial plants. The thoroughness with which they examined the manufacturing side of Detroit was to us very interesting, and it was quite a revelation to witness

the wonderfully minute detail with which the Japanese will examine and take notes in making an investigation.

"These men went into our industrial plants with their note books and their pencils in hand, and they would stand in front of a machine until you fairly dragged them away, noting down little points and making drawings in hieroglyphics which none of us could decipher. I recall one very prominent manufacturer of this city saying to me as he noted this, 'I will tell you it is not a good thing for the Japanese to come over here to study our methods and see what we are doing, and to copy it all. In about ten years you will find they have produced over there in the Orient a duplicate of our Occidental results, and you will find these activities we now set such great stress upon installed in Japan. Then we will have to compete with cheap labor, and they will overload our market with their products.' There was another gentlemen present, a man of large experience, and a good deal of breadth of view. He said: 'I do not believe any such thing. If they copy all these things as we have them now, we will soon be so much further ahead and they will be about ten years behind.'

"In this connection I am reminded of that poem of Kiplings, 'Mary Gloster,' in which you recollect Mandalays, the great assemblyman. Before the old gentleman dies he talks to his son. As he calls him to him he says the following:

" 'They asked me how I did it,
And I gave them a scriptural text;
"You keep your light a-shining,
A little in front of the next."

" 'They copied all they could follow,
But they could not copy my mind,
And I left them seething and sweating
A year and a half behind.' "

(Applause.)

Major Speer. "Mr. President, I wish to offer a resolution and trust it may meet the approval of the Association. It is a resolution which recognizes the ability of Dr. Joseph A. Holmes, and recommends him to the Directorship of the new United States Bureau of Mines. We from Pittsburgh know Dr. Holmes, and for the last couple of years have been in very close touch with him. He has been doing great work for us under government auspices in his tests of safety devices in mines, fuel tests, etc.

"Resolved that the American Foundrymen's Association in convention assembled, recognizing the ability, integrity, and qualifications of Dr. Joseph A. Holmes, respectfully petitions the President of the United States to appoint him as Director of the newly created Bureau of Mines.

"Further, that the Secretary be instructed to send a copy of this resolution to the President of the United States, and wire him in the name of this Association."

(Also a similar resolution to be sent to the Secretary of the Interior.)

The Secretary. "May I say a few words on this resolution? It is put before the Association just now, out of the regular order of business, because this matter is a very serious one at Washington at the present moment. Dr. Holmes has worked for us year after year in connection with our coal and coke questions, and is going to do some more things for us in the great testing laboratory in Pittsburgh. Dr. Holmes is the best man for the appointment and members of Congress have petitioned for it, but there is a movement going on in Washington to sidetrack him, and for that reason we desire to do something for our old friend Dr. Holmes."

The resolution being duly supported, and put to the convention, prevailed unanimously.

President Waterfall. "The vote carries, there being no nays, and the Secretary will please arrange for forwarding the telegrams along the lines indicated."

NOTE.—*By the Secretary.* President Taft sent no acknowledgment of the telegram, and Secretary Ballinger, of the Interior Department, had his private secretary send a short note of acknowledgment.

The result is well known, Director Smith, of the U. S. Geological Survey, being appointed temporary director of the Bureau of Mines, the pressure for Dr. Holmes having been too strong from all parts of the country for the President to ignore.

PRESIDENTIAL ADDRESS

President Waterfall. "It is the regular order of business each year to expect the president of the allied associations to make some sort of formal address at the opening of the convention. What I shall say I do not say because anything that I might say is of any great value.

"Gentlemen and members of the American Foundrymen's Association, the American Brass Founders' Association, the Foundry Foremen's Association, the Foundry and Manufacturers' Supply Association, and visitors who may be here, you show by your presence that you are chiefly interested in obtaining knowledge. The fact that a large number of foundrymen will travel hundreds of miles to discuss with their fellow foundrymen the latest development of the art shows the necessity and the reason for the existence of such associations as are meeting here in this building to-day.

"This is the fifteenth convention of the American Foundrymen's Association, and those of you present who can look back to the earlier years and remember the difficulties in getting men with the courage to tell of their experiments

and their successes in producing a better class of work and at a less cost, will note to-day the willingness of foundrymen to give this information to their chosen industry. No longer do they surround the foundry with the air of mystery that formerly enveloped it, realizing now that in the interchange of ideas we are mutually helped. If we give the other man some little thing of value in our discussions, we, in turn cannot fail to absorb from him some information of the result of his labors that is equally as valuable to ourselves.

"The policy of the American Foundrymen's Association is purely educational. We welcome the employees and the employer equally to freely discuss the question of how to do good work. We do not discuss nor consider, in our association work, the question of labor nor the prices of the product.

"To those of you who have visited the magnificent exhibit in the Manufacturers' Building on these grounds by the Manufacturers' and Supply Association, I would call attention to the marvelous devices to assist the worker in the foundry, lessening his toil, making his occupation a pleasanter one to follow and making the foundry worker's occupation as desirable as in any of the other arts.

"The marked advance in the foundry art, as we look back the past year to see the developments, is encouraging—the making of castings in a permanent mold; the extension of the continuous pouring arrangement in the foundry, whereby the blast goes on in the morning and molds are poured continuously all day. Then some foundries show a wonderful exhibition of ingenuity and skill. The development of the electric furnace, the electric smelting of ores, the electric melting of non-ferrous metals for our use in the foundry, all show advances.

"During the past year, in accordance with a resolution passed at the convention in Cincinnati last summer, a mail vote was taken last month on the proposition of increasing the dues from $5 to $10 a year. The necessity of this increase of

dues became apparent to most of us, to meet the cost of our large amount of printed matter, the information asked for by our members, secured from other members who had a working knowledge of some particular portion of the work, and supplying after each convention a bound volume of the proceedings to each member. We have had something like 190 personal requests during the last few months for this bound volume. I have personal letters expressing the hope that the mail vote would carry making the dues ten dollars a year in order that the work of the association should not be impaired. Some things are being paid for by some gentlemen personally which ought to be paid for by the members, for we get something valuable and we ought to pay for it, and I am glad to say the mail vote carried, so that the dues will be ten dollars.

"The citizens of Detroit have just awakened this morning to the fact that we have a convention out here, I learn this from the number of telephone messages and inquiries, and that this exhibit is gotten up at a very great e pense and trouble, some of you can perhaps appreciate. I was asked how such an exhibition would pay, and I am very glad to tell you, gentlemen, that the State Fair Association through its board of directors and president tendered us the use of these grounds and buildings as a tribute to the foundry industry of Detroit. I want to make that known to you; I want to make it known that their courtesy was so freely extended, and I want to let them know that we appreciate it, and we, in turn, hand over these buildings and grounds to the Supply Association. I want the State Fair Association people to feel that we appreciate it." (Applause.)

President Waterfall. "Gentlemen, on the programme which we wish to carry out, there is a response to the mayor and to Mr. Larned's address. Mr. Joseph S. Seaman, of Pittsburgh, who represents the past presidents of the American Foundrymen's Association, will now respond to the addresses of welcome."

Mr. Seaman. "Gentlemen, I have had the pleasure of attending all the conventions of this organization as held in the past fifteen years. I am not prepared to stand before you and make a very eloquent address in response to the addresses you have heard from the Mayor and Mr. Larned. I merely rise to say that we do not think that our Association has met at any city where the welcome was more liberal and cordial than it has been in Detroit.

"We arrived here on Monday morning and were met by many friends, and it has been a very hearty welcome—and shaking of hands with everybody. Your Mayor has met with us, and we see the preparations you have made to welcome us, we see them on every side, I know we will appreciate your welcome very much." (Applause.)

REPORT OF THE SECRETARY-TREASURER

Ten years have now elapsed since the American Foundrymen's Association was good enough to entrust me with the executive work pertaining to this office. From the splendid nucleus of Foundry Pioneers, constituting the Society at the time my energetic predecessor turned over this work to me, a great Association has developed, the like of which may be found nowhere in the world. Go where you will among the civilized Nations of the earth, and you will find us well known not only for the excellence of work done, but more particularly for the spirit which animates the membership to give freely of experience and advice to those who search for advancement, without desire of recompense—yes often to a possible business detriment.

When contrasted with the liberal minded who see in the advancement of the industry as a whole a direct gain to the world, and who do their share either in work or by contribution, or oftentimes both; how sma l is the individua

who sits by without helping, but just the same appropriates any ideas that come along for his advantage. We need more men of broad views. An industry embracing such an enormous number of foundries as North America can show up, should give us members by the thousand instead of hundred.

Yet we have done well, and with so many warm-hearted members standing behind the organization, there is little wonder that it is looked to as representing the most advanced practice, as furnishing the debating ground for proposed changes in method, as furthering the betterment of employee and employer alike—for on the broad platform of honesty and truth there is no division. The success of our Association is primarily due to its individual members, and long may they hold their friendship and regard for it.

During the year I found it necessary to go to Europe twice. The first time right after the convention; the strain from Cincinnati having proved so heavy that it became a question of health to get away, and I combined a visit to the Western and Central parts of Europe with some interesting investigations into the industrial situation of the countries in question. Beginning at Christiana, the trip went through Stockholm, Copenhagen, and Berlin, thence through the iron districts of Western Germany to Brussels, then Paris, Marseilles, the beautiful Riviera, Florence, eternal Rome, Naples and home. While in Copenhagen, besides meeting the redoubtable Dr. Cook, of North Pole fame, I attended the International Association for Testing Materials Congress, at which our Vice-president, Mr. Walter Wood, and a few other well known American Scientists attended. Mr. Wood and I represented the United States in matters relating to cast iron, and the friendships cemented with the famous Englishmen, Germans, and members of other Nations whose names are household words in Iron Circles will remain bright spots in my life. From the opening exercises in the presence of the Royal Family to the closing banquet at Elsinore amid the booming of guns, it was a wonderful and withal instructive

gathering, the result of which so far as cast iron is concerned is the getting closer on the several questions of international specifications.

During this trip, at the instance of the U. S. Government, I also gathered information on the subject of accidents in mines, factories, and the like, industrial insurance, and more particularly the complete laws in force in the several countries visited, as related to these subjects. These have all been turned over to the respective authorities, and as I took occasion to travel slowly and where I could speak the language, in third class carriage, I got into conversation with fellow travelers and thus learned more of the social conditions than could be gotten in any other way. For the student of political economy, and particularly one who has the welfare of this Country deeply at heart, this information was highly interesting, and showed that not only here do we have the mad race for luxury with all the attendant evils—and God knows what is yet to follow—but also in staid Germany, frugal France and Belgium, are the conditions exactly the same, from the highest in the land down to the poorest peasant. If we add to this, cases that I found where men pay out 15% of their annual income in taxes so that war armament, royalty, etc. are kept up, it is little wonder that there is a cry to get back to nature again.

The second European trip was a short one, for business in foundry matters, and I took occasion to look particularly into the difference between German and American foundry practice. The Foundrymen of North Germany were good enough to call upon me for an evening's talk, and a great assemblage of Foundrymen and Engineers from all over North Germany were pleased to listen to a general talk on American foundry practice. They send their warm regards to us, and wish us everything that is good.

If I can point to but one great difference in practice, it is that Germans—and I understand the English also—make their castings entirely for the work intended, no matter if the machine shop kicks about hard castings. If they want

wear they make their castings in accordance therewith, and no excessive machine shop costs—as we might think them—are allowed to stand in the way. A little of this method would do us good here, where the foundryman is constantly on thin ice when he sends out his castings to a machine shop. We are too much after soft castings here, as you all can testify.

Further when going into the question of pig irons, strange to say their better brands—and more expensive ones—are all of the rather lower silicon varieties. Quite evidently they still believe in paying high for an imported metal that has a name for making strong castings. Some day the fact that other irons with low silicon will do the same will be recognized, and then our customs will get closer together.

To turn now to internal affairs. The Association now has 753 members, which number excludes those who are in bad standing and cannot be gotten to pay up their annual dues. What effect the raising of the annual dues to $10 will have remains to be seen. Let us hope that it will not materially affect the membership, particularly as it is the intention to enlarge the Transactions, and to furnish a bound volume at the end of the year. This action, now that the vote has passed it, was highly necessary, for although the books show a balance, if the absence of the Secretary for three months in Europe, had not meant that the Association was under no expense during that time, there would probably have been a deficit to show. This will be noted from the expense now necessary for convention arrangements, and the enormous work of the office, requiring as it did the round sum of $500 in postage.

The finances of the Association are as follows:

Balance from last year..................	$28.64
Income during year.....................	2,940.00
	$2,968.64

Expense for Transactions	....	$1,178.53
" " Printing	....	135.75
" " Postage	....	500.00
" " Salaries	....	900.00
" " Convention	....	222.47
" " Sundries	....	11.61
		$2,948.36

This leaves a balance of $20.28 to report to the Association.

The work on special investigations is moving along, reports not being ready at this time for publication. The Laboratory of Mackintosh, Hemphill & Co. under the direction of our good Mr. H. E. Field, kindly analyzed all the molding sands for us (in connection with the tests now going on), special credit for this work belonging to Mr. F. H. Daniels, chemist. The fund has a balance of $340.42, as only $2.97 was expended during the year, and that for freight, etc.

I conclude my report, which is a rather hasty one, as the convention preparations have kept me exceedingly busy until the last minute, with expressing my thanks again to my many friends who at Philadelphia presented me with that token of esteem which besides forming a permanent monument for my after life, also made possible this magnificent European trip. To the members of the Association, my warmest thanks for their forbearance and uniform courtesy during these ten years of service, and with faith in the future of our great industry and the kindest of feelings toward our Membership, whom I hope long to serve if they so wish it, I remain,

Respectfully,

RICHARD MOLDENKE,

Secretary-Treasurer.

Mr. Seaman. "As we all know, Dr. Moldenke has served us very faithfully. I have known him ever since, I might

almost say, his boyhood. He was elected secretary of this organization years ago, when everything was going along very slowly. We went on year after year, and he reported everything paid up, as he is doing to-day. This went on until the convention in Cleveland, when, as a good many of you know, possibly, the matter was taken up and a fund raised to pay, at least, in good will, something extra. He appreciated it as something very extraordinary when we were not doing anything more than paying him what he really was entitled to. Now I do not want to take up the time of the convention but I simply want to say this, he makes his report this morning 'Paid for salary, $900.00.' He is entitled to $1,200.00 by the resolution of the convention. There are other salaries besides his which he has paid and how far he has been paid, I do not know. He knows. Now I want to get a resolution before this convention to the effect that the executive committee of this association take up the matter of salary paid Dr. Moldenke and to see that he gets what he is entitled to."

The motion having been supported, the president said: "You have heard the motion and the support of it to the effect that our Secretary-Treasurer needs to have an auditing committee to see whether he paid bills out of his own money or not. Now those in favor say 'Aye' the contrary 'Nay'. It is carried, Doctor, and you have an auditing committee on your books."

"The next item is a paper by Steelman Stephenson, on Acetylene-Oxygen Repairs in the Foundry. With an exhibition of the art as practically applied."

THE USE OF THE ACETYLENE-OXYGEN FLAME IN THE FOUNDRY.

By Steelman Stephenson, Detroit, Mich.

In the acetylene-oxygen flame, the foundryman has had a new agency for facilitating the work of his plant, and in increasing the output of merchantable product of his shop.

Both acetylene and oxygen are gases long known, but it was only with the advent of the electric furnace, and the production of calcium carbide that the former gas became a commercial possibility. Everyone now knows the process of producing acetylene by the action of water on calcium carbibe, for the bicycle lamp, the auto-headlight and the isolated lighting plants using this gas have introduced it to the remotest corner of the land.

A number of processes are in use for commercially preparing oxygen, and the writer investigated them all when beginning the business, with the final selection of the gas produced from liquid air. This gas possesses the highest degree of commercial purity, and in particular is free from any hydrogen, a component which is exceedingly dangerous when compressed with oxygen, and one that is potentially a possibility in all oxygen made by electrolytic or chemical means.

When these two gases, acetylene and oxygen are burned together under pressure, the temperature produced is the highest that is practically attainable by chemical means. The devices for producing the combustion are more complex than those needed for the combustion of hydrogen, on account of the unstability of the acetylene, which is very prone to decomposition and polymerization, when exposed to either moderate pressure or heat.

The most successful burners are of the ejector type, in which a stream of oxygen under suitable pressure, sucks another stream of acetylene into the combustion area. Very elaborate gauze packings are needed in the burner tube to prevent the flame striking back to the source of acetylene, which will burn itself without the presence of air or oxygen, or rather undergo a chemical change, if heated to any very high degree.

With a proper burner, a temperature approximately 6300 degrees F. can be attained at the hot tip of the cone of the flame. The rate of combustion is so great that the most infusible substances melt under the application of this hot cone, and heat production proceeds so much more rapidly than radiation, that a fused spot can be produced on the surface of any material.

All the products of the foundry have melting points below 3,000 degrees F., hence the usefulness of this agent becomes evident. One of the first applications to come to mind will be the filling of sand holes etc. in castings. We all know how often a casting otherwise good is rejected for a hole found in it under inspection. Various forms of iron cement will remedy some of these castings, but others do not offer suitable hold for the cement, or are weakened by the location of the hole. With this flame, metal of the same constitution as the casting may be melted into the hole, dressed off, and a perfectly homogeneous casting will result—one that will defy criticism. Bosses that have not filled out in the running, strain cracks appearing on cooling of improperly designed castings, and even new parts on a casting, overlooked in the pattern, may all be handled with the skilled use of this flame.

By suitable proportioning of the gases in the flame, either oxydizing or reducing effects may be obtained.

A very practical use of the oxydizing flame may be made in the use of it as a cutting agent. Sprues and fins may be cut off in a minimum of time, and if properly handled, no

further finishing of the casting is necessary. Once the surface of the metal is heated white hot, a jet of high pressure oxygen may be directed against the hot spot, with the production of rapid oxidation, or burning of the iron, and the line of combustion will act as a saw, leaving no wider a kerf, with perfectly good metal on each side.

As to cost, the flame from a No. 8 Fouche burner, with proper allowance for labor and overhead, will cost about six cents a minute. In many cases a dollar's worth of work can be done in that minute, hence the process commercially is practicable, as well as useful.

NOTE.—*By the Secretary.* Mr. Steelman Stephenson now gave a number of most interesting demonstrations bearing out the points of his paper. Bars of steel were cut through with the greatest ease. Similarly plates. Finally an automobile cylinder, which had been cracked was patched up by melting off cast iron from a pencil of that material and applied to the joint. Mr. Stephenson enjoyed the interest of the assemblage, the subject being a new one to most of those present.

The meeting then adjourned until the afternoon.

SECOND SESSION

Tuesday, June 7, 1910. 3 P. M.

Meeting called to order by the President.

The President. "It gives me great pleasure to introduce Mr. Benjamin D. Fuller, of Cleveland, Ohio, who will give us a paper on 'Foundry Efficiency.' "

Mr. Fuller. "I wish to state that what I have to present before you is hardly worth the dignity of being called a paper. It is simply bringing you the result of ideas which we have put into operation in the foundry. I am here at the suggestion of the manager of our company, Mr. Taylor."

FOUNDRY EFFICIENCY

By Benjamin D. Fuller, Cleveland, Ohio

The question of raising the efficiency of the shop is ever a live one, be it the Machine, Pattern, Smith, Boiler Shop or Foundry. Hence, I feel it will not be trespassing upon the time of this body to ask you to devote a few minutes to the consideration of methods which have been tried and, so far, proven successful.

First, consider the question of excess weight on castings due to careless ramming, weak flasks and loose bars, weak boards, soft pit walls, etc. What does it mean? Not only a poor casting, but an expensive one in many ways. If it be a small casting, say one properly weighing 5 lbs., the order calling for the delivery of 1,000 daily, and you produce 1,000 castings which, due to some negligence, average 5½ lbs., then the day's work shows 500 lbs.

excess weight at .008 per lb., equals $4 per day for the one pattern, iron cost only. Now while the foundry will probably receive credit for the extra weight, it means a loss, however, to the Company, who charge a certain figure for the finished equipment.

Another loss is in machining, as jigs will not fit properly, etc., and when your foundries are in one city, and your machine shops in another, there is the extra freight charge from foundry to factory, and again the extra freight charge when shipping the finished equipment. If the casting is a heavy one, such as an engine or generator bed, armature, spider, field frame, etc., something weighing 15 to 40 tons, the case is more marked, a variance of 1,000 lbs. or more in two castings from the same pattern is not extraordinary. This, when your freight shipments are thousands of tons monthly, means much.

Now awaken a live interest in this question in your foremen, and the result is not only a saving in dollars and cents, but the satisfaction of noting a marked improvement in the quality of output. In our case a card record of shipments by pattern number is kept, upon which card weights are recorded as separate shipments are made. When gains or losses show, the case is tabulated in a monthly report, which is totaled at the close of the month, each foreman's department being segregated.

Many disagreeable surprises are in store for any one compiling such a report, but when the foremen are gathered to discuss the question, and marked cases are brought to their attention, it "sinks in," with the result that, as in our case, it shows a decided total gain.

Following up this matter has also emphasized the advantage of the molding machine, as invariably the transfer from hand to machine molding shows a decided gain in quality, as well as reduction in weight. This may not appeal to the man who sells his castings by weight, but it will appeal to his customer from both standpoints.

In the machine shop the removal of surplus stock is an item of expense which is coming in for more attention than

has been accorded in the past, and a close communion between machining and casting departments will produce results which are at times surprising. As for instance, a certain line of motor castings produced in large numbers in the foundry with which I am connected have recently been the subject of a considerable exchange of comment and suggestion as to ways and means toward reducing the amount of labor in finishing. Quite a gang of chippers being employed in the foundry upon the line and again in the machine shops before the work would pass critical inspection.

A method of pattern construction was devised which so simplified the molding as to produce castings which averaged 1½ hours per piece less chipping in the foundry, a saving of the labor of five or six men per day. A saving, which is not so marked, but still enough to be a factor. The great difference is noted in the machine shop where the labor saved in finishing is considerable.

A striving to improve a record among the foremen, must needs awaken an ambition among the men, and nothing is better for the shop than to get the men interested in a sort of contest of this kind.

Another method being employed, and which promises well, is an efficiency record, whereby a report is tabulated daily showing the amount cast in pounds by each man, the amount good and amount bad. The per cent. of scrap made in each department, or bay, in a given period, usually from one pay to another, and whether a man is over or under the average of his bay for this period.

A foreman's record is determined by the average of all the men working under him. This individual record is kept by card index, so that any man may be shown up at any time. No bluff as to "how good you have been" can be carried out in the face of this record. And on the other hand, the deserving can be singled out. This card record is of considerable value when men ask for advance in rate from time to time. By a glance it is easy to determine a man's comparative value. For instance, if a man's

record shows that he has made more scrap than the average of his department, you would not waste much time in argument with him.

Copies handed to each foreman of a daily tabulated report showing the number of castings made from each pattern, and the number which were defective, in a parallel column for comparison, will also "help some."

The coremaker is also kept tab upon, and opportunities afforded the ambitious, as well as means used to stir ambition among the men and boys. Here is a method of handling the yard labor, such as loading and unloading cars, piling and transporting stock, iron, scrap, coal, sand, limestone, clay, etc. If you have kept a record whereby each operation has been segregated as to cost, it is an easy matter to strike an average as to the cost of the whole, using as a base the average cost per ton to you at present, or the best figure you have recorded. Offer a good man in charge of the whole yard force a premium for every fraction of a penny per ton he can beat this record price. Do the same with the cupola operator as to the costs which enter into his work, charging coke, iron scrap, ladle and cupola care, etc., etc. The same with the man responsible for the cleaning and chipping of the castings, and you may be surprised at the results.

Do not make a move which will weaken the men's confidence in your fairness, and in the words of the Immortal Abe Lincoln, "There may be other things which your special case requires to make you happy, but, my friends, these I reckon will give you a good lift."

During the reading of his paper, Mr. Fuller added a few points in explanation, which are given herewith:

"The Foreman is always brought up when a report is made showing the total loss and total gain which has been made in the separate departments. When there is a decided loss in weight in castings made, he is asked to explain For

instance, we shipped last month say, twenty thousand pounds and shipped this month twenty-eight thousand pounds. There is something wrong It is for the foreman to get at it and figure out why castings show eight thousand pounds one month more than the other month off the same pattern. It looks like a complicated record, but it is not so. Our office force tables up this record for us. They spend one day in every two weeks and a decidedly full and accurate record is kept of each and every molder, who is given a check number. We do not tabulate his work up by pattern number, we simply tabulate the amount of pounds produced on every man's score each day, the amount which was good, and the amount which was bad. Then we strike an average. We take an average of the lowest in that day for two weeks to see whether this runs the man below or above the average of the department in which he is working. This is kept up to date and is brought up every two weeks.

"It is a pretty good thing to have such a tabulation and examine the records when a man comes to you and says he is worth more money. You need not spend much time in arguing with him.

"We put the giving of premiums and rewards for efficiency in force with a man who was in charge of the outside labor, taking off the very best record that had been made. Of course we had confidence in whom we were talking to. We called him in and showed him his record, that it was the best he had ever done and if he could beat that record we would divide with him half of what he could make. That man has been making twenty-five to fifty dollars a month ever since we offered him this premium. The number of men has been cut down considerably and we find it no trouble at all. That department takes care of itself, and the foreman says that he has good men and they are well satisfied in every way." (Applause.)

The President. "Since there is no discussion on the paper, we will proceed next to Mr. West's paper on the 'Personal Equation in Accidents in Foundries.' "

THE PERSONAL EQUATION IN ACCIDENTS

By Thos. D. West, Cleveland, Ohio

Recently the Minnesota Employers' Association and the Federation of Labor jointly petitioned the Governor of the State, asking an investigation by the Legislature looking toward a change in the present system of compensation of employees in case of accident, in which the element of risk of the industry is recognized. Among the sixteen clauses, we find the following statement: "We are convinced that the majority of accidents that happen in the course of employment, occur by reason of dangers incident to the employment, and without fault upon the part of either employer or employee."

The document in question is notable, as it shows a commendable spirit of fairness between employer and employee, but the question arises whether the proper basis has been chosen to work upon. Is not perhaps the fact that when a trade is designated as dangerous, it is made more so by such official action, for things may be encouraged that can have a direct influence on causing accidents? Far better if attention is directed toward increasing watchfulness, the exercise of sound judgment, and fidelity to duty; for while it is commendable to give adequate compensation for injuries received, great care should be taken that a state of affairs is not created tending to increase accidents. How seldom is even a reasonable compensation sufficient to atone for the suffering that results, especially if the outcome is fatal.

From the experience of the writer both as employee and employer, and his investigations along the lines of accidents, their causes and remedies, he is certain that any unbiased and thorough investigation will show that the great majority of accidents is the result of personal carelessness chargeable directly to the individual, his lack of obedience to instructions, error in judgment, and neglect of duty. An excellent authority on railroad accidents, Mr. James O. Fagan, on page 52 of his valuable book

on *Confessions of a Railroad Signalman,* says that fully 85 per cent. of the fatalities that occur on railroads can be directly traced to the negligence of employees. What holds good in one industry, so far as accidents are concerned, is often applicable to all the others.

As this is a matter that we have all to face squarely at any hour in our daily life, we might as well have the truth. We are liable to be killed or maimed continually, and it is not nice to see all the dodging that is being done in handling the question of responsibility at the present day.

To advance the doctrine that the majority of accidents in a trade are incident to it, and neither the employee nor employer is at fault, is a step likely to have serious results, for it takes away most of the sense of personal responsibility from the operative, and makes him heedless regarding the effect of his actions upon the safety of others.

We are daily killing and maiming 1,600 persons in this country. If the idea of the non-responsibility of the person in the majority of accidents is to prevail, suppose we try to answer the following question satisfactorily to ourselves:

1. Is it possible to so equip our street cars that careless or dull-witted motormen cannot run over people?

2. Is it possible to so install signal systems that the personal element of the train despatcher can be wholly ignored?

3. Is it possible for an engineer to disregard instructions at will and yet always bring in his train safely?

4. Can the judgment of the wheel-tester be dispensed with and chances taken in sending out trains under any methods we know of, eliminating the man?

5. Is there any way the responsibility of the pilot at sea can be done away with?

6. Can the elevator operator have his mind on foreign topics, and not some time or other injure his passengers?

7. Is there any way, except through your own watchfulness, that you can cross busy streets without running grave chances?

8. In running automobiles, is there any way of avoiding accidents to self and others, except by the strictest attention and cool judgment?

9. In handling guns, powder and fireworks, is there anything except sane judgment which will prevent accidents, which on the fourth of July alone amount to 5,000 deaths and serious injuries, in this country?

10. Is there any automatic way of preventing conflagrations caused by lighting matches carelessly? If so, we could save something like fifty millions annually.

Now let us take up the mill and mine.

11. Is there any rule by which an operative may always take the proper sized chain to make a safe lift, or attach the tackle properly, erect poles, move loads, and the like?

12. Can the crane operator be inattentive occasionally, and yet not injure some one?

13. The firing of boilers, handling of safety valves, speeding of machines, even the selecting of proper threads for bolts. Can we do without the intelligence of the workman or his proper judgment?

14. Regarding the use of electricity, safety lamps, explosives, etc. Is it not a fact that nearly all the great mine disasters are the result of deliberate carelessness on the part of some one man who thus is the cause of death and disaster to many others?

Many more questions could be put, covering a still wider range of observation, such as liability of accident from drinking, smoking, stupidity, deliberate inattention, and horseplay. At the very time of penning these lines, the writer was summoned to the

spot where a fine young man was killed as the result of skylarking with a companion, trying to pull away a small belt from him, while being over a smooth shaft, and the other on the ground. For the foundry in particular, we have the careless use of water, hard ramming, poor venting and drying of cores and molds, bad joints, poor flasks, improper clamping and weighting of molds, and badly daubed, dried and handled ladles.

The writer by no means wishes to screen the employer who does not do his part in helping to prevent accidents. It is the best kind of a policy to furnish all practicable safety devices and to instill into the minds of the operatives a sense of caution and forethought. There is no denying the fact that the employer or foreman, by watching out for those carelessly inclined, may do much toward preventing them from damaging themselves and others. Of course, this means an added load of worry, but inasmuch as accidents with their attendant suits and judgments jeopardize investment, this load had better be assumed as an insurance.

Attention must be called to the tendency on the part of employees to run things to their entire liking, if allowed, and the consequent increase in the accidents of a shop where this condition of affairs exists. As an example of this, we have one large establishment in which the men bring in intoxicants in open buckets right past the watchman and the officials, to consume them when and where they please within the works. This is surely a direct bid for accidents.

Prevention of accidents by the removal of all the factors that tend to cause them should be our watchword. Nor should we hesitate to point our fingers to the proper places for fear of censure. An honest effort is needed on the part of both employers and employees to remedy individual faults, the doing of which would cut down 80 per cent. of the accidents in shops. Let this be accomplished, and the question of compensation will take care of itself, besides wiping out so much of that misery and sorrow we see daily.

The operative must be taught that his part is by far the most

important in the life of the shop, so far as liability to accidents is concerned; and that the doctrine advanced that accidents are inherent to certain industries irrespective of the conduct of either employer or employee, is a grave and dangerous fallacy.

The President. "There being no discussion on Mr. West's paper, and Mr. Custer, whose address on the 'Permanent Mold' was to come next, being unfortunately too ill to come to Detroit, Mr. Henry Cave, of Springfield, Mass., will give us an illustrated talk on 'Autogenous Welding'; gentlemen, Mr. Cave."

Mr. Cave gave a running description of a large series of lantern slides, and afterward sent in the following memoranda of his address, naturally much shortened on account of the absence of the illustrations.

AUTOGENOUS WELDING

By Henry Cave, Springfield, Mass.

Autogenous Welding is the uniting of metals by heat alone, without the intervention of any other metal.

The blacksmith's weld is not Autogenous, because he uses pressure to bring the parts together; brazing is not Autogenous, because a different material is used to unite the parts; the Foundryman's "Burn" is really Autogenous Welding, but the heat is obtained from a large mass of molten metal. The system we are discussing, however, obtains its heat by means of the combustion of Acetylene with pure Oxygen, which produces a temperature of 6,300°. What this temperature means can best be realized by the fact that if an ordinary thermometer registering up to the boiling point, is eight inches long, it would have to be extended twenty-one feet to measure this temperature on the same scale.

The reason for Acetylene giving such an intense heat when burned with pure Oxygen is due to the large amount of carbon in its composition, and also to the fact that the nitrogen in the air is eliminated, resulting in the intense flame, which can readily melt a section of a casting of any size.

It is necessary however, where a weld of any thickness is required, to remove the metal by making a groove, so that the flame can come in contact with the metal on the bottom, which is fused, and then additional metal can be added from a rod of the same metal until the whole becomes one solid mass. In this way metal can be added to increase strength or change the design, such as the addition of bosses, or to fill in places where the mold has not filled, to weld up blow holes, or to replace parts that have been broken off, or to weld up shrinkage or other cracks.

The weld when ground has the appearance of the orginal material, and also the strength of the same. Tests of cast iron welds have shown a strength of twenty-five thousand pounds per square inch.

In considering the uses of this equipment, Foundrymen should bear in mind that the value of their defective castings to them is not only the labor expended on making the mold, as is frequently assumed, but that the percentage of defective castings also means a proportionate increase of pro-rata expenditures, this is particularly the case where a foundry is running to its full capacity, as the castings saved are a direct increase in production, without any material increase of pro-rata expenses, and in many cases if the castings were scrapped and new ones made, there would be the same percentage of loss in the new ones, and this also should be borne in mind, in considering the possibilities of making a saving by the use of the Oxy-Acetylene torch.

It should be noted when considering the saving to be made, that there are two distinct types of welding equipments on the market, which are termed "High" or "Positive Mixture" torch equipments, and the "Low" or "Injector Type" torches. Owing to the fact, that the mixture is positively regulated in the first type, a consumption of Oxygen of only 1.28 to each unit of Acetylene is obtained, with the result that the welds are not oxydized, and have the maximum possible strength.

The "Low Pressure" or "Injector Type" torch obtains its mixture due to the flow of Oxygen drawing in the Acetylene, with the result, that the mixture is not uniform, and uses from 1.5 to 1.8 of Oxygen to each unit of Acetylene. The first type of torch therefore shows an economy of 25 to 40% in Oxygen, and there is an additional saving of about 20% on time consumed, making in all a saving of about 50% on the cost of carrying out the work, as well as producing much stronger welds. .

This process also is considerably used in the steel foundry

for removing risers. This is carried out by means of an Oxygen jet, and is based on the phenomenon shown by the elementary scientific experiment of inserting a red hot iron wire into an atmosphere of Oxygen which will immediately cause it to burn.

In cutting, a small spot is heated up by means of the Oxy-Acetylene flame, and a jet of Oxygen is projected on to this hot metal from a separate orifice, the metal being burned or oxydized away where the jet strikes, with the result that a cut is made similar to that produced by a saw.

Extensive tests have been made as to the cost of carrying out this work and it has been proved that steel risers can be cut up to 6 inches in diameter at a cost of 1 cent per square inch, whereas the cost of cutting by cold saw under the same conditions was 1.5c per square inch. The torch cut 150 square inches per hour as against 27 square inches for the cold saw. The figures for the cost of cold-sawing, do not take into consideration power consumed, or renewal of the saws.

The Oxy-Acetylene cutting equipment costs considerably less than the cold saw, and it is capable of carrying out the same amount of work as five of these saws, the floor space being proportionately less, so that there is a very great advantage in every way.

The meeting here adjourned until Wednesday A. M., at ten o'clock.

CONVENTION SMOKER

A "Smoker" was given by the Detroit Foundrymen's Association to the visiting members of the allied Associations. The great hall of the Light Guard Armory was filled to its

utmost capacity with happy, enthusiastic people, out for an enjoyable evening. Mr. Woodison, the Master of Ceremonies for the occasion, entertained the gathering by reminiscences of times gone by, and called upon various members present to say a few words. Among those who responded was our old fellow-member John Hill, the "biggest" Supplyman of them all. In a few happy words he recounted the rise and spread of the movement which has culminated in the great exhibitions now held. He emphasized particularly the desirability, nay the necessity, of raising the standard of the conventions continually upward, and in this way opening up the best business conditions possible.

A fine selection of Vaudeville, splendid "Souvenir Steins" to take home with you, and filled up to your own liking, together with an excellent lunch while enjoying the entertainment, made up a pleasant evening for all.

LADIES' THEATRE PARTY

An admirable Ladies' Committee took care of the visiting ladies during the convention week, and spared no time or trouble to make every one comfortable. Indeed the work must have been very exhausting, for the members of the Ladies' Committee were constantly engaged at Headquarters or on the several trips planned for the entertainment of the visitors.

On the evening of the Smoker, the visiting ladies were entertained by a Theatre Party, which, judging from the enthusiastic accounts of the 225 ladies who attended, must have been a highly enjoyable affair.

THIRD SESSION

Wednesday, June 8th, 11 *A. M.*

The meeting was called to order by President Waterfall.

President Waterfall. "We will open the morning session of the American Foundrymen's Association with the report of the committee on Chemical Standards for Iron Castings by Dr. J. J. Porter, whom I introduce to you."

Dr. Porter here presented his report as follows:

CHEMICAL STANDARDS FOR IRON CASTINGS.

A Report to the American Foundrymen's Association by John Jermain Porter, Chairman of Committee

FOREWORD

It was at first intended to make this report a simple tabulation of compositions used for the various classes of castings together with recommendations in each case. In carrying this out it seemed desirable to give some general rules whereby the practical foundryman might for himself work out a suitable mixture for castings in which certain physical properties were desired. From this its scope has been gradually extended until it has reached its present voluminousness.

As it stands, the report is divided into five parts, as follows:

PART I. *The Constitution of Cast Iron.*—This is written primarily for foundry chemists and others wishing to go into the reasons why. Some knowledge of chemistry and metallurgy is assumed of the readers of this part.

PART II. *The Properties of Cast Iron.*—This is a discussion of the relationship between the various physical properties and the chemical composition of cast iron. It is hoped that it will prove of some value to the practical man in charge of foundry operations.

PART III. *Chemical Standards for Iron Castings.*—A tabulated statement of compositions used for each of the various classes of castings, together with a tentative standard, or best composition, suggested by your committee. The data on which

this table is based is taken partly from published results, but chiefly from the replies to inquiries sent out by the committee.

Part IV. *A Directory of Brands of Pig Iron.*—This gives some of the more essential particulars concerning each brand of foundry pig on the market. The data are not entirely new, but it is thought that foundrymen will here find it in a more convenient and accessible form than elsewhere.

Part V. *Bibliography.*—A more or less incomplete list of books and papers on the subject of cast iron, its chemical composition and physical properties. These are numbered and references made to them by number throughout the text.

A word of explanation regarding the personnel of the committee doing this work is due the association.

The writer, it will be recalled, was appointed chairman with power to select his own committee. It was not stated how many members the committee should have, and knowing through sad experience the difficulty of securing efficient team work in a matter of this kind, he decided to limit the number to one, consisting of himself. He is obliged, therefore, to assume entire responsibility for all defects and inaccuracies in this report, and is earnestly hoping that his shoulders may be strong enough to carry the load.

In conclusion the writer wishes to acknowledge the invaluable assistance and encouragement of his wife in the preparation of this report, and to thank in behalf of himself, the A. F. A., and the foundry industry those foundrymen who, in answering his inquiries, so generously gave the results of their experience.

JOHN JERMAIN PORTER, Chairman,
University of Cincinnati.

PART I

THE CONSTITUTION OF CAST IRON

Cast iron is a complex alloy containing usually six elements, but sometimes more. Since these may be combined with each other in various ways the number of constituents possible is still greater and the complexity of the alloy is correspondingly increased. The elements invariably present in cast iron are, in the approximate order of their importance, iron, carbon, silicon, phosphorus, sulphur and manganese. In addition, copper, nickel, oxygen and nitrogen are of quite frequent occurrence and aluminum, titanium and vanadium are sometimes added.

IRON

Iron occurs in three allotropic forms, known respectively as *alpha*, *beta*, and *gamma*. These exist normally at different temperatures. As shown by Fig. 1 the *gamma* is the stable form above 1680°F., the *beta* form between 1440° and 1680°, and the *alpha* form below 1440°. According to the allotropic theory of hardening, the *gamma* and *beta* forms of iron may be preserved at ordinary temperatures by very rapid cooling. This, more especially, in the presence of carbon which is supposed to exert a brake action and retard the change from one form into another.

The characteristics of these three forms of iron are quite different. The *alpha* form is ordinary iron as we know it at ordinary temperatures in unhardened steel. It forms one of the constituents of slowly cooled gray pig iron.

Beta iron is non-magnetic and differs from *alpha* iron in several other important respects, such as specific heat and density. Professor Howe has recently suggested the identity

of *beta* iron with martensite (129)*. If this be true, *beta* iron forms the chief hardening constituent in hardened steels.

Gamma iron is also non-magnetic and is different in specific heat and density from both the *alpha* and *beta* forms. It is very hard but less so than *beta* iron (if *beta* iron is martensite).

Pure iron is an unsuitable material for making castings as it would be impossible to get them free from blowholes. On the other hand, its physical properties are very good for many purposes. In cast iron a high percentage of iron is very desirable and increase in any metalloid beyond what is absolutely essential to give the necessary soundness and softness can only be harmful to the other properties.

CARBON

Carbon is the element which gives cast iron most of its characteristic properties. It is generally said to exist in two forms, free and combined, but in reality its action is much more complex. What is known as free carbon includes graphite in all its physical states, ranging from kish to temper carbon, and combined carbon includes not only the well known cementite, Fe_3C, but also the so-called hardening or solution carbon, which is usually considered to be a solid solution of carbon in iron, as well as several transition forms between the hardening carbon and cementite which have been considered by some to be definite compounds. In addition, cementite may differ in its physical condition since it may be present as a structurally free constituent or as one component in an intimate mechanical mixture with ferrite known as pearlite. In hardened steel, especially, the form of combination of carbon is a matter of much uncertainty. Campbell (71) has suggested that carbon may form with iron a series of ferro-carbons having the general formula, $Fe_3n\ Cn$ and that these may crystalize with various amounts of iron of crystalization. Table I gives in tabular form the various forms of carbon or iron-carbon compounds of which we are fairly sure, together with some of their more important physical characteristics.

*NOTE.—The numbers in parentheses throughout the text refer to the *Bibliography*, Part V.

TABLE I

FORMS OF COMBINATION OF IRON AND CARBON

Name	*Synonyms*	*Physical Characteristics*
Graphite	Free Carbon	Very soft, dark flakes of variable size. No strength.
Kish	Free Carbon	Graphite in very large flakes.
Temper Carbon	Free Carbon	Graphite in form of very fine powder.
Ferrite	Iron	Soft, very ductile, low strength.
Cementite	Combined Carbon Iron Carbide, Fe_3C	Very hard and brittle, high static strength, no ductility.
Austenite	Soln. Carbon in *gamma* iron	Slightly softer than martensite also weaker and more brittle.
Martensite	Soln. carbon in *beta* iron (?). Transition product austenite to pearlite.	Hard, but less brittle than cementite. Chief constituent of hardened tool steels.
Troostite	Transition product martensite to sorbite.	Softer than martensite, less brittle and more ductile.
Sorbite	Transition product troostite to pearlite.	Softer than troostite and more ductile. Strongest form.
Pearlite	An intimate mechanical mixture of cementite and ferrite.	Very strong, harder than ferrite.

The construction of the iron-carbon equilibrium diagram has been the subject of a vast amount of work and still we are in considerable doubt as to the cast iron end of it. The latest, and probably the most nearly correct, representation, has been given by Upton (73, 98) and is here reproduced in greater part in Fig. I.

This diagram applies only to pure iron-carbon alloys, which are supposed to be cooled with extreme slowness. The first condition is approximated in the case of some very low silicon white irons, as for example, cold-blast charcoal irons. The second condition, however, is never reached in commercial practice, the cooling of castings never being sufficiently slow to get the results shown by the diagram. According to Upton (73, p. 40) what happens is that the *gamma* inversion at 2003° F. is suppressed entirely and the cast iron as cast consists simply of a solid solution of carbon in iron with a little graphite as shown by the area *CBFG*. The graphite may, however, be entirely absent if the cooling is sufficiently rapid, due to the complete suppression of the transformation on the line *BD*. On this theory Fe_3C is not important, in fact, not present in

commercial cast iron, that which has been considered as cementite being really a solution of carbon (and silicon) in *gamma* iron.

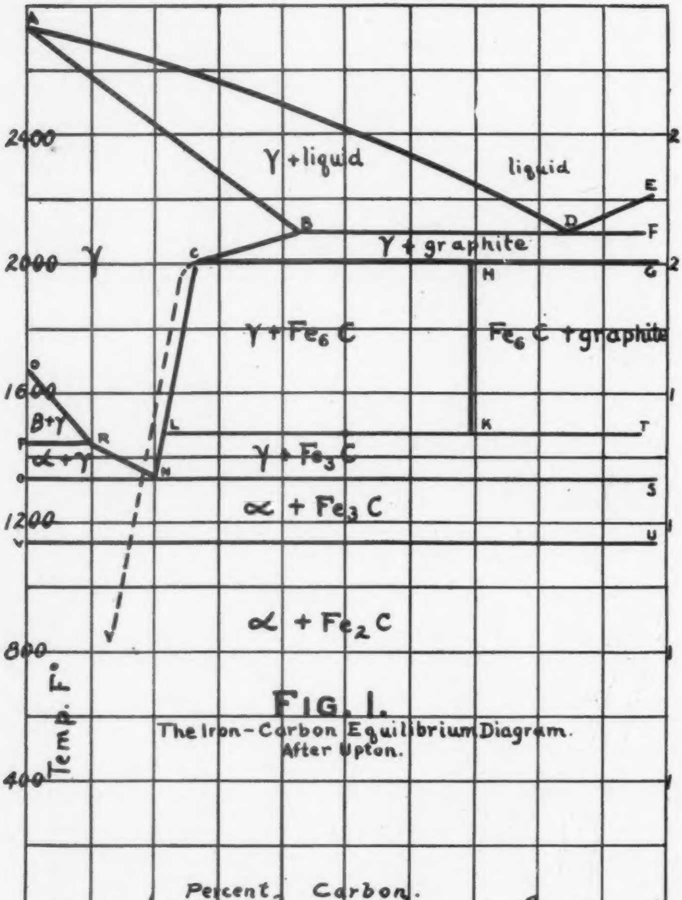


FIG. 1.
The Iron-Carbon Equilibrium Diagram.
After Upton.

Evidently this equilibrium diagram does not tell us much in the case of ordinary cast iron. Where it does come in, how-

ever, "is in giving a consistent basis of reasoning as to the direction in which changes should go." (73, p. 414) For example:

"If the white cast iron be reheated, it is to be expected that the first reaction to occur will be the one which was suppressed during the chill casting, viz., the formation of graphite. This means the reduction of the supersaturated solid solution back to saturation. The saturation line for graphite in contact with carbon solution in *gamma* iron is the line *BCY* of Fig. 2 (our Fig. I). The white cast iron, on reheating to a red heat, will then form graphite internally until the equivalent carbon in solution reaches the value shown by *BCY*. Since this line shows decreasing carbon in solution with reduction of temperature, more graphite will be formed the lower the temperature at which the white cast iron is annealed. That such is the case has many times been shown. . . . . . ." (73, p. 409)

By chemical analysis we can distinguish only two forms of carbon, graphite and combined, and this being the case it is customary in considering it from the practical standpoint to take into account only these two forms. That is, all kish and temper carbon come under the head of graphite, while solution carbon and its transition forms as well as cementite are included in the term "combined carbon."

The total carbon, or the sum of the graphite and combined carbon, is dependent upon the conditions of melting in blast furnace and cupola and upon the percentage of silicon, sulphur, phosphorus and manganese.

When iron is melted in contact with carbon it tends to take up carbon until saturated at that temperature. Hence, a very high temperature in the blast furnace means a high percentage of total carbon, other things being equal. For this reason coke irons are usually higher in total carbon than charcoal irons, the temperatures at which they are made being greater.

When iron is remelted in the cupola it tends to become saturated with carbon at this temperature and hence, may

either take up or lose carbon depending upon its previous content.

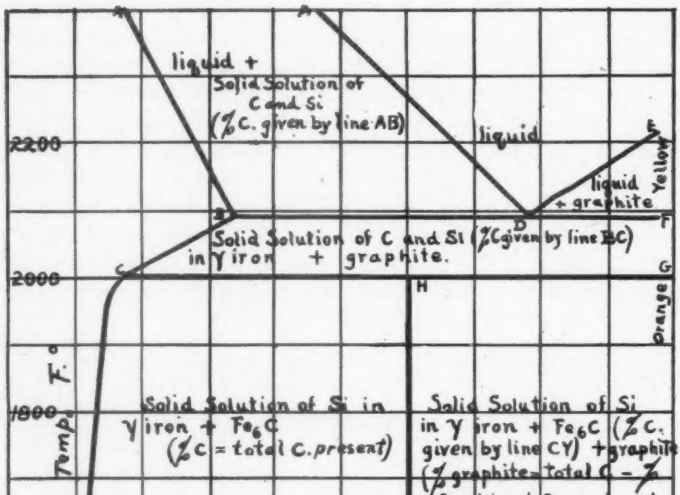


FIG. II.
Iron-Carbon Equilibrium Diagram.
1% Silicon

The presence of silicon, sulphur and phosphorus decreases the solubility of carbon in molten iron while manganese in-

creases it. In iron melted under conditions which permit equilibrium to be reached the percentage of total carbon will be

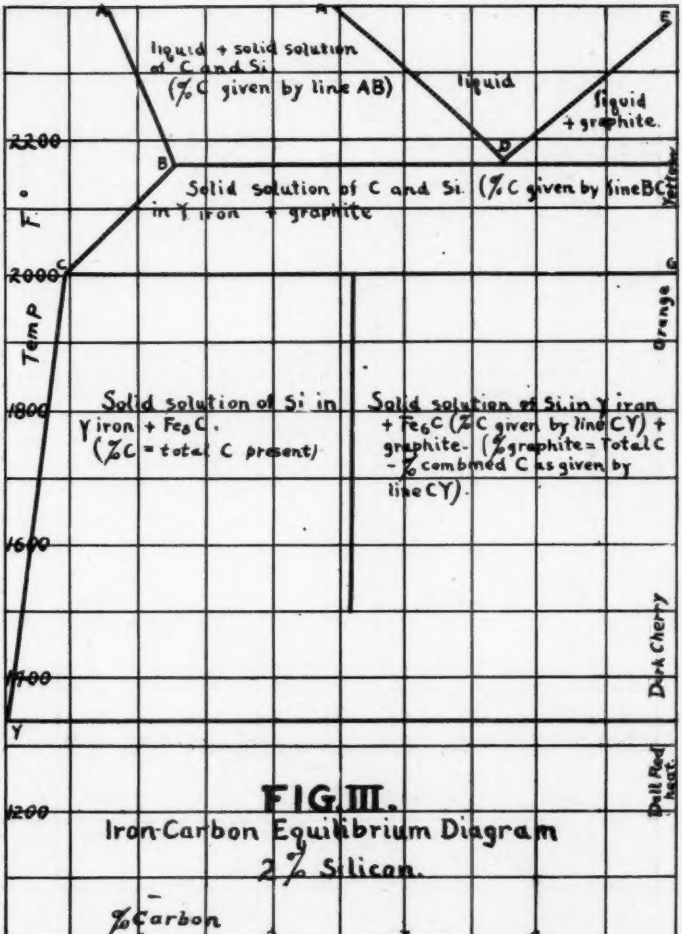


FIG. III.
Iron-Carbon Equilibrium Diagram
2% Silicon.

4.23—.27×%Silicon—.32×%Phos.—.3×%Sul.+.03×%Mang. The theoretical relation between percentage of silicon and total

carbon (assuming all other metalloids low) is shown in Fig. VI, and on the same diagram are plotted a large number of total

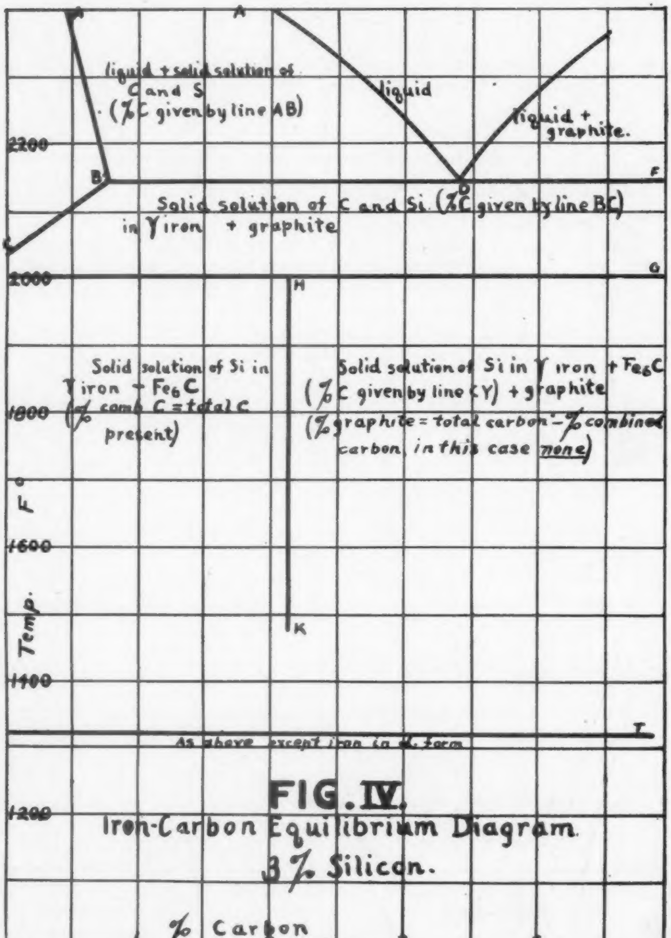


FIG. IV.
Iron-Carbon Equilibrium Diagram.
3% Silicon.

carbons as found in actual castings, thus showing how closely the actual approaches the theoretical.

Graphite weakens iron in which it is present in proportion to the amount, and, even more important, to the size of the flakes. In large flakes, the extreme of which is kish, it gives cast iron a very coarse or "open" fracture and makes it very weak and porous. It does not of itself soften iron, but with any given total carbon, the higher the graphite the lower the combined carbon and hence, the softer the iron. Graphite does, however, act as a lubricant to the tool in the machining of cast iron, and thus has an effect which is practically equivalent to softening.

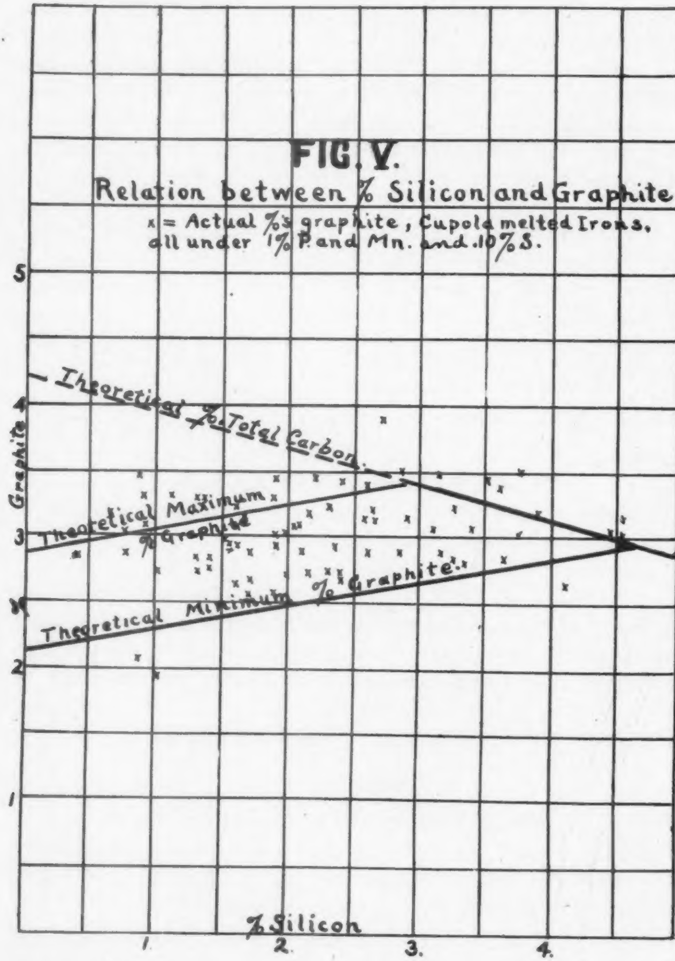
The amount of graphite in any cast iron is a function of five factors, as follows: A.—% total carbon. B.—Rate of cooling. C.—% silicon. D.—% sulphur. E.—% manganese. Phosphorus also has some slight effect, but in the amounts present in commercial cast iron it is so small as to be practically negligible.

A.—The importance of total carbon follows from the iron-carbon diagram, Figs. I, II, III, or IV. All other conditions being fixed the combined carbon is fixed and since the graphite is equal to the total carbon minus the combined carbon, it is therefore dependent on the total carbon.

B.—Rate of cooling. This is a matter of common experience and also follows from the iron-carbon diagram. For every cast iron there is some maximum percentage of graphite which is the normal amount. The actual amount will be something less than this, depending on the rate of cooling and consequent degree of suspended equilibrium.

C.—Per cent. silicon. Silicon affects carbon in two ways, first by reducing the amount of total carbon present by .27% for each % silicon, and second, by decreasing the amount of combined carbon, i. e., by precipitating .45% combined carbon out as graphite for each % silicon. Hence, under conditions which permit equilibrium in the percentage of total carbon in the melt to be reached, the amount of graphite formed will be .45—.27=.18% for each % silicon. While under conditions of melting where the iron is not in contact with carbon,

and hence, the total carbon remains constant, the graphite will be increased .45% for each % silicon. This assumes that all



other conditions, including the rate of cooling, remain constant. (See also under "Silicon" pp. 52 to 57.)

D.—Per cent. sulphur. The influence of sulphur is to retain carbon in the combined state and prevent its precipitation as graphite. The numerical value of this effect is uncertain, but there is approximately .045% less graphite for each .01% sulphur present.

E.—Per cent. manganese. The influence of manganese is similar to sulphur in that it tends to retain carbon in the combined state and thus to decrease the graphite. The numerical effect is roughly about .4% less graphite for each increase of 1% in manganese. This assumes manganese present as carbide, since, as explained under the head of "Manganese," (p. 64), if present as *MnS*, it has less effect.

The expectation of graphite, omitting the effects of sulphur and manganese, i. e., assuming these normal, in a cast iron melted in a cupola with conditions favoring exact saturation with carbon, i. e., excess of coke, low blast pressure, high tuyeres and large receiving ladle, is shown in Fig. V which expresses diagrammatically the equation

$$\text{Minimum graphite} = 4.23 - 2.10 + .18 \times \%\ \text{silicon.}$$
$$\text{Maximum graphite} = 4.23 - 1.35 + .18 \times \%\ \text{silicon.}$$

(See also p.55.)

The normal limits of graphite for both silicon and total carbon varying are shown in Table II which is calculated from the expression.

$$\text{Minimum graphite} = \%\ \text{total carbon} - 2.10 + .45 \times \%\ \text{silicon.}$$
$$\text{Maximum graphite} = \%\ \text{total carbon} - 1.35 + .45 \times \%\ \text{silicon.}$$

Combined carbon hardens iron and decreases its ductility in direct proportion to the amount present. Up to a certain point it increases the strength and beyond this point decreases it again. The percentage of combined carbon giving the greatest strength is probably about 1%, but the problem is rendered very complicated through the fact that all carbon not present in the combined state will be present as graphite and in that form is weakening in all proportions.

TABLE II

NORMAL GRAPHITE LIMIT FOR VARYING SILICON AND TOTAL CARBON.

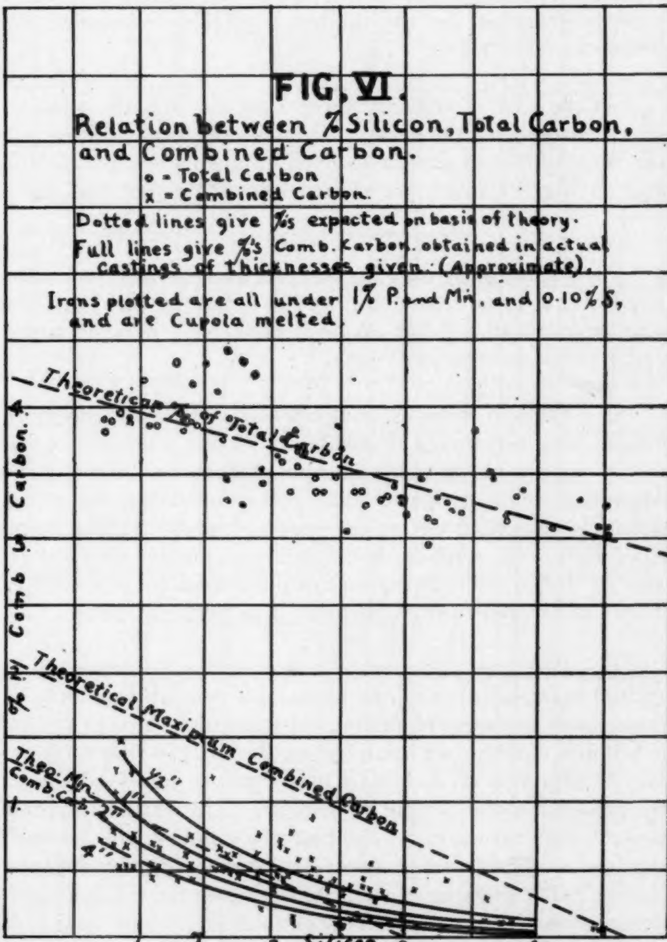
% Silicon	% Total Carbon	2.00	2.50	3.00	3.50	4.00
0.5	max.	.87	1.37	1.87	2.37	2.87
	min.	.12	.62	1.12	1.62	2.12
1.0	max.	1.10	1.60	2.10	2.60	3.10
	min.	.35	.85	1.35	1.85	2.35
1.5	max.	1.32	1.82	2.32	2.82	3.32
	min.	.57	1.07	1.57	2.07	2.57
2.0	max.	1.55	2.05	2.55	3.05	3.55
	min.	.80	1.30	1.80	2.30	2.80
2.5	max.	1.77	2.27	2.77	3.27	3.77
	min.	1.02	1.52	2.02	2.52	3.02
3.0	max.	2.00	2.50	3.00	3.50	4.00
	min.	1.25	1.75	2.25	2.75	3.25
3.5	max.	2.00	2.50	3.00	3.50	4.00
	min.	1.47	1.97	2.47	2.97	3.47
4.0	max.	2.00	2.50	3.00	3.50	4.00
	min.	1.70	2.20	2.70	3.20	3.70

These expressions hold fairly well for the foundry grades of iron. For the low silicon irons the tendency to chill is very great and the graphite is apt to be less than indicated.

The factors which control the percentage of combined carbon are as follows: A.—% silicon. B.—Rate of cooling. C.—% sulphur. D.—% manganese.

A.—Per cent. silicon. Of these the percentage of silicon is of the greatest importance to the founder. The range of combined carbon which should result for each percentage of silicon (the cooling being normal i. e., the casting being neither chilled nor annealed), is given by Fig. VI which is calculated on the basis of the theory explained on page 54. On the same diagram are plotted the actual combined carbon contents of a great many castings. These show the variation from theory which is found in practice.

B.—Rate of cooling, or what amounts to the same thing in ordinary foundry practice, size of section, is scarcely less



important than percentage of silicon. The composition remaining the same, the more rapid the cooling, through a certain

range of temperature, the greater the amount of combined carbon in the castings. This means that where castings of a certain percentage of combined carbon are desired, the silicon must be increased for the thinner sections to counteract the greater rate of cooling.

In the case of ordinary green sand castings the relationship between the thickness of section, per cent. silicon and per cent. combined carbon is given approximately by the full lines in Fig. VI which are plotted from the actual data there given.

As explained on page 56 the rate of cooling through the solidification range, 2,200° to 2,000° F., may be rapid and the combined carbon still low provided the cooling between 2,000° and 1,300° F. is sufficiently long.

C.—Per cent. sulphur. Sulphur has a marked tendency to increase the percentage of combined carbon, especially when as *FeS* in the absence of sufficient manganese. Each .01% sulphur is commonly stated to be able to neutralize about .1% silicon in regard to effects on combined carbon. This being true, each .01% sulphur should increase combined carbon by .045%. Howe (128) found that in pig iron each .01% sulphur caused an increase of from .02 to .03% in combined carbon.

D.—Per cent. manganese. As explained farther along (p. 65) manganese acts in an anomalous manner depending on the relative amount of sulphur and manganese present. Since it will first combine with sulphur as *MnS* and in that form has very little action on carbon, it may decrease combined carbon by preventing the action of sulphur. Any further addition beyond that necessary to combine the sulphur will, however increase combined carbon due to the formation of manganese carbide. The amount of manganese to care for the sulphur is about three times the per cent. of sulphur present, and each per cent. of manganese above this amount will, roughly, cause the presence of about .4% combined carbon.

Phosphorus has only a very slight influence on the carbon

of iron, so slight, indeed, that in the amounts in which it is ordinarily found in cast iron (under 1%) its effects may be

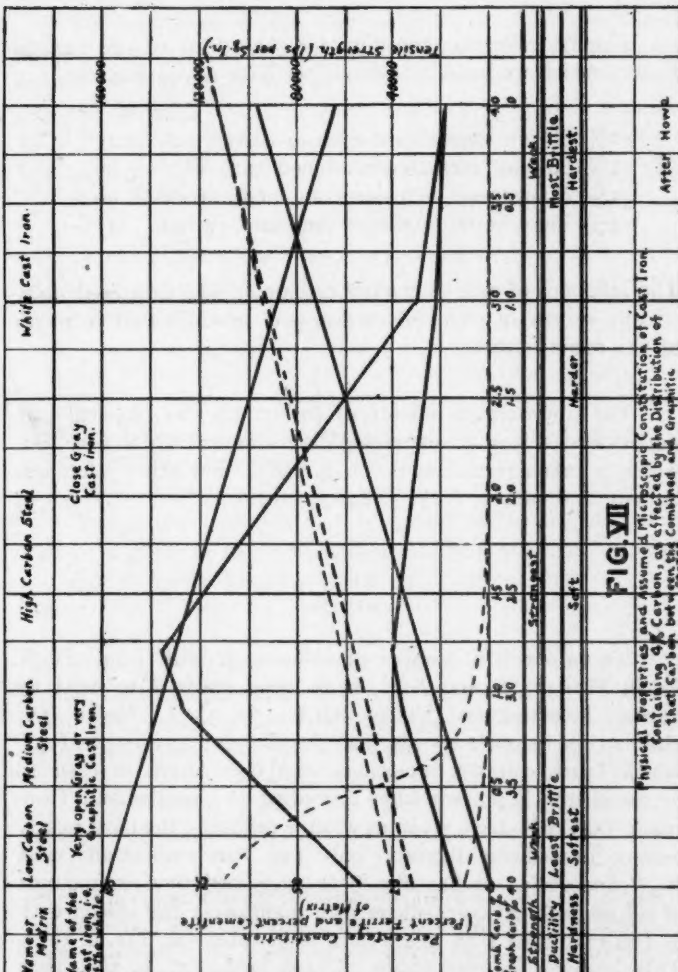


FIG. VII

Physical Properties and Assumed Microscopic Constitution of Cast Iron Containing 4% Carbon, as affected by the Distribution of that Carbon between the Combined and Graphitic States.

considered as negligible. According to the theory enunciated on page 59, 1% phosphorus should increase combined carbon

by .17%, but it may be doubted if it has even so great an effect as this.

Finally, collecting the data for the effects of the various factors which we have considered, we have approximately,

1% Silicon decreases combined carbon	.45%
1% Sulphur increases combined carbon	4.50%
1% Manganese increases combined carbon	.40%
1% Phosphorus increases combined carbon	.17%

The influence of rate of cooling cannot be well expressed numerically except in terms of thickness of castings cast in molds of the same nature.

The approximate effects of carbon on the physical properties of cast iron are expressed diagrammatically in Fig. VII, which is taken from Howe (74, p. 438). For other references on iron and carbon (128, 5, 84, 74, 102).

SILICON

Silicon forms a number of compounds with iron. Fe_3Si, Fe_2Si, $FeSi$, $FeSi_2$ and $FeSi_3$ have been claimed to exist by various investigators (78, 59, 97, 54, 62, 131). Naske (59) claims that in ordinary pig iron the silicon is present as Fe_3Si which forms complex molecules with iron atoms in case an excess of iron is present while according to Guertler and Tammann (54), who have given us what is probably the most nearly correct iron-silicon diagram, only two true compounds exist Fe_2Si and $FeSi$. It has also been suggested that compounds of silicon with sulphur, silicon with manganese and silicon with carbon may exist with cast iron in some cases (38, 131, p. 197). This, however, is improbable. Upton holds (73, p. 398) that silicon is present in ordinary cast iron as a solid solution and this seems to be the most probable theory. Whether it is present as a solid solution of the element silicon or as a silicide is im-

material. In rich ferro-silicons, such as are made in the electric furnace, free silicides are no doubt present.

The properties of the solid solution of silicon or silicide in iron vary with the percentage of silicon. With increasing silicon content there is increasing hardness and brittleness. There is probably a slight increase in strength for small amounts of silicon while with large amounts there is a notable decrease. High percentages of silicon render iron very resistant to the action of acids (138).

The chief effects of silicon upon cast iron are through its action on the carbon. They may be summarized under two heads as follows:

A.—Increasing the silicon decreases the total carbon.

B.—Increasing the silicon increases the proportion of total carbon existing as graphite.

The action of silicon under A comes of its property of replacing carbon in the molten solution, thus making the liquid eutectic of lower carbon content. As Upton states it (73, p. 404):

"In blast furnace or cupola melting where the iron is in intimate contact with carbonaceous fuel, the tendency of the cast iron is to run the total carbon content up toward the 'saturation' value, which is really the carbon content of the liquid eutectic. When silica is added to a melt of iron and carbon the liquid eutectic carries less carbon than does the eutectic of iron and carbon alone. . . . "

The quantitative relationship between the per cent. of silicon and the total carbon has been determined by Wust and Petersen (78) and their results may be represented by the formula:

$$\% \text{ total carbon} = 4.23 - .269 \times \% \text{ silicon}.$$

It should be understood, however, that the total carbon is only reduced by silicon in case the metal remains in a molten state sometime after the addition of the silicon, so that the displaced carbon (graphite and kish) has an opportunity to float to the surface and become lost to the iron.

The action of silicon under B, that is, in increasing the graphite, is probably caused by its replacing the carbon atom for atom in the solid solution. That is, 28 parts of silicon replace 12 parts of carbon, or 1% of silicon replaces (or precipitates as graphite) .43% carbon. Experimental results indicate that .45% carbon are precipitated by 1% silicon which is in sufficiently close agreement with the theory.

Now, since 1% silicon decreases the total carbon by .269% in the liquid eutectic and then throws out of solution .45% of the combined carbon in the solid solution, the net result (in the case of cast irons melted under conditions which permit equilibrium of the carbon content to be reached) is an increase of .181% graphite for each per cent. silicon.

On the basis of this theory, which is due to Upton (73), Figs. II, III, and IV have been constructed, and making proper allowance for the suppression of some of the inversions due to too rapid cooling in commercial castings, it is believed that nearly all the phenomena observed in commercial cast iron can be coordinated and explained by means of these diagrams.

Fig. II refers to the cast iron series of the iron-carbon alloys containing 1% silicon and is, therefore, applicable to such irons as are used for chill castings, malleable work, etc.

Let us first follow the cooling of an ordinary car wheel iron containing 1% silicon and, say, 3.50% carbon. This iron when cooled slowly from the liquid state begins to solidify when the temperature crosses the line *AD* (at 2120° F.), crystals of a solid solution of carbon plus silicon in *gamma* iron separating out. The percentage of carbon in these crystals separating at 2120° is given by the ordinate to the line *AB* corresponding to this temperature, or about 1.5%. As the temperature falls

the per cent. of carbon in the crystals increases along the line *AB*. When the line *BD* (2093° F.) is reached the liquid eutectic remaining solidifies, and in doing so splits up into an eutectic mixture of graphite plus a solid solution of 1.65% carbon in *gamma* iron.

Evidently at this stage the iron consists of a solid solution of 1% silicon plus 1.65% carbon in *gamma* iron plus 3.50 — 1.65 = 1.85% graphite. If cooling progresses sufficiently slowly the solid solution of carbon in *gamma* iron precipitates graphite and becomes less concentrated, its composition changing along the line *BC* to a minimum of .85% carbon. At this point the changes cease since in commercial castings the rate of cooling is never slow enough to permit the transformation along the line *CG* to take place, and the only other transformation is the change of the *gamma* into *alpha* iron at the line *YT* (1337° F.). The final distribution of carbon in the very slowly cooled iron would, then, be .85% combined carbon and 2.65% graphitic carbon.

The above reasoning has been based on ordinary slow cooling as is the case with castings of heavy section or with sand cast pig iron. In case the cooling is more rapid, a part of the transformation within the area *BCGF* will fail to take place so that the final concentration of the carbon in the solid solution (combined carbon) will be somewhere between the limiting values of 1.65 and .85%. With still more rapid cooling, as in the case of chilled castings, separation of graphite along the line *BDF* is more or less completely prevented, so that the solution carbon may be anything up to 3.50%, the total amount of carbon present.

In the case of irons containing 1% silicon but less than 3.50% carbon the case is similar, the solution carbon being the same but the graphite less since it is given by the difference between the total carbon and the solution carbon.

If the total carbon is above 3.80% instead of the solid solution of carbon in iron we will have graphite separating out from the liquid melt after it crosses the line *ED*. Hence the iron will

be more difficult to chill and in order to get a perfect chill, all the carbon being in solution, it will be necessary to pour from a temperature above the line *ED* as well as to cool very rapidly.

If a chilled iron containing 1% silicon be reheated the first reaction to occur will be that one which was suppressed during the casting, *i.e.*, the formation of eutectic graphite which should have taken place at the line *BF* and in the area *FBCG*. If sufficient time be given the solution carbon will be reduced to some percentage on the line *BCY* depending on the temperature. The graphite will be the difference between the total carbon and the solution carbon, and since it is formed in the solid metal it is very finely divided. This then, is the explanation of the formation of temper graphite by annealing in the manufacture of malleable castings.

Fig. III shows a similar diagram for iron-carbon alloys with 2% silicon. It will be noted that the eutectic point, the line *HK*, and the points *B* and *C* have all been moved to the left by the addition of the silicon. Evidently ordinary sand castings containing 2% silicon and normally cooled will contain from 1.20 to .40% solution or combined carbon corresponding to the limits *B* and *C*. If chilled sufficiently rapidly such an iron may retain all its carbon in the solution form but there will be a far stronger tendency to precipitate graphite than in the case of 1% silicon iron. This is particularly the case when the carbon is over 3.64%.

The explanation of Custer's process (40, 93) of casting in permanent iron molds may well be considered here. This process, it will be recalled, consists in pouring the metal into very heavy cast iron molds, allowing it to just set and then dumping out the castings at once so that they may cool slowly in air. Castings so treated are not appreciably harder than similar castings made in sand molds in the ordinary manner. By casting in the chill, the iron passes so quickly through the solidifying range (2200 to 2000° F.) that the graphite formation on the line *BDE* is largely suppressed. However, on removing from

the chill, the temperature being about 1800° F., this suppressed reaction takes place and continues at a decreasing rate as the iron cools slowly down to about 1300° F. At this temperature, the line *YT*, the change of the iron from the *gamma* to the *alpha* state takes place and coincidently, the separation of graphite probably ceases. As a result of the graphite being formed in this manner in the solid metal, it is much more finely divided and regularly distributed, and hence, weakens the iron much less. In addition the segregation of phosphorus and sulphur is largely prevented by the rapid cooling and their evil effects are greatly lessened.

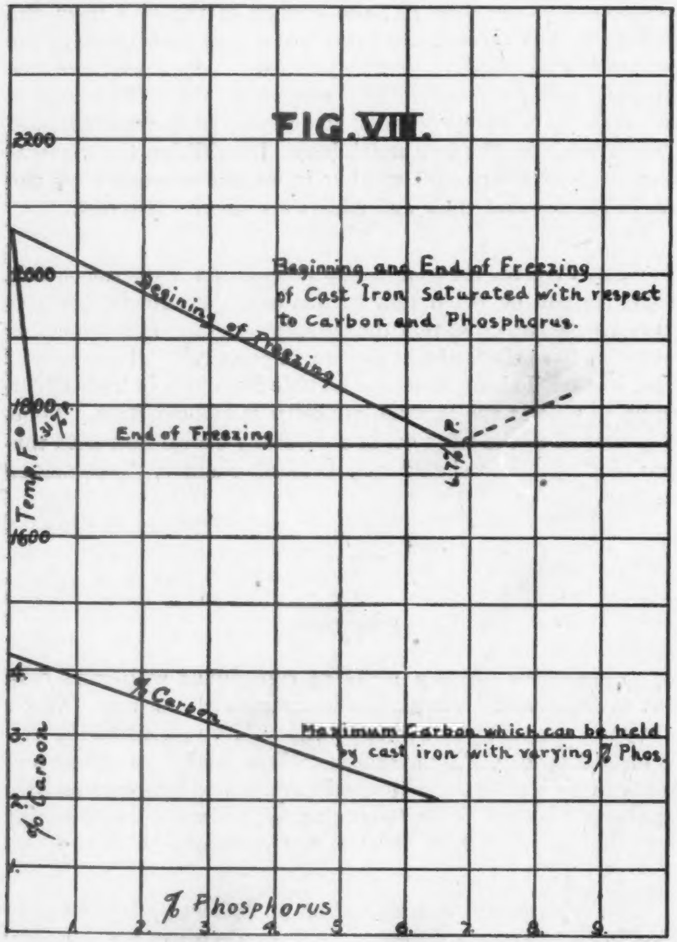
Fig. IV gives the iron-carbon diagram for a 3% silicon cast iron. It will be noted that in this case the eutectic contains only 2.90% carbon so that the graphite separates in considerable quantity from the liquid in the case of practically all commercial cast irons. This explains the trouble from kish in high silicon irons as well as the extreme difficulty of chilling them. Point *B* is moved to the left so that a normally cooled iron with this per cent. of silicon should vary between 0 and .75% combined carbon.

PHOSPHORUS

Phosphorus forms a series of compounds with iron, only one of which, Fe_3P, is important in commercial cast iron. When alloyed with pure iron a solid solution of iron phosphide in iron is formed up to 1.7% phosphorus. With higher percentages of phosphorus a eutectic of this solid solution with iron phosphide appears; this eutectic containing 10.2% phosphorus and having a melting point of about 1800° F. (48, 49, 140).

In the case of an iron-carbon-phosphorus alloy, *i.e.*, the cast irons, the case is different. Carbon decreases the solubility of phosphorus in solid iron and therefore precipitates it from the solid solution. With 3.50% carbon it is possible to have 3.1% phosphorus in solution, but in case less phosphorus than

this is present, some will still be precipitated. The greatest amount of phosphorus which can be present and still remain



entirely in solid solution in the presence of 3.50% carbon appears to be about .07%.

The eutectic formed by these elements is ternary containing 2.0% carbon, 6.7% phosphorus and 91.3% iron, and has a freezing point of about 1740° F. (142). The phosphorus is contained in this eutectic in the form of Fe_3P as in the case of the carbon free alloys. Wust has found (142) that the amount of carbon which can be taken up by iron is decreased by the presence of phosphorus and vice versa. The relationship is given by Fig. VIII. Wust also states that whereas an iron containing 4.27% carbon and .02% phosphorus solidifies at 2066° F., an iron with 2.15% carbon and 6.19% phosphorus begins to solidify at 1765° F., while solidification is complete at 1742° F. In other words, each additional 1% of phosphorus lowers the temperature at which solidification begins about 49° F. The transformation at 1320° F. is stated to be unchanged by the addition of phosphorus.

From all this we see that the net effect of phosphorus is to lower slightly the temperature at which solidification begins and, to a much greater degree, the temperature at which it is completed. Thus, freezing takes place through a wider range of temperature and this in turn results in greater ease of separation of graphite. Quantitatively the addition of 1% phosphorus to cast iron containing 3.50% carbon and 2% silicon approximately:

Lowers the temperature at which freezing begins from 2200 to 2150 or 50° F.
Lowers the temperature at which freezing ends from 2165 to 1740 or 425° F.
Increases the temperature range of solidification from 50 to 375° F.

Upton interprets the effect of phosphorus on the state of existence of carbon as follows: (73, p. 398.)

". . . Carbon displaces phosphorus from solution in the iron and the phosphorus then goes into the form of Fe_3P. But the phosphorus in Fe_3P uses up some of the iron which might otherwise be caring for carbon; and so there results an in-

creased concentration of carbon in that part of the iron which remains uncombined with phosphorus . . ."

". . . addition of 1% phosphorus would increase graphite by 0.12 – 0.15%, . . ."

"The effect of phosphorus on the liquid eutectic is similar to that of silicon, reducing the carbon content. The numerical value of the effect is – 0.32 . . ."

Microscopic work has shown that the phosphide eutectic when formed in low carbon metal has a tendency to form cell walls which being brittle greatly weaken the mass. In cast iron the phosphide generally gathers into small globules and in this form has less effect on the strength. However, if it can be altogether prevented from segregating, as by rapid cooling through the solidifying range, its weakening effects are almost entirely prevented.

SULPHUR

Sulphur exists in cast iron in two forms, iron sulphide and manganese sulphide, these having somewhat different properties.

Iron sulphide is a hard, brittle substance having a melting point of about 2175° F. or about the same as the iron-carbon eutectic. It forms, however, an eutectic with iron containing 16% iron and 84% iron sulphide (30.5% *S* and 69.5% *Fe*) which melts at 1780° F. (155, 156). Iron sulphide dissolves in all proportions in molten iron and up to about 2% in molten cast iron, but is only slightly soluble in solid iron and is practically insoluble in solid carburized iron. In the freezing of cast iron, therefore, the iron sulphide is rejected in the form of the iron-sulphur eutectic as the iron-carbon-silicon solid solution crystalizes out. This eutectic, because of its low freezing point, remains fluid after the rest of the mass has solidified and is thus squeezed out into the

intercrystaller spaces forming separating films. These films are of extreme thinness and correspondingly great extent and because of their brittleness they can exert a weakening effect out of all proportion to the weight of sulphur present.

Manganese sulphide has much the same physical characteristics as iron sulphide. That is, it is a hard, brittle substance of about the same melting point. It is, however, insoluble in the molten iron-carbon-silicon solution as well as in the solid. It is, perhaps, owing to this, or possibly because it possesses a high surface tension that it is invariably found segregated in little globular masses or droplets throughout the iron, and these, because of their slight area, have but little weakening effect.

The affinity of manganese for sulphur is greater than that of iron, the molecular heat of formation being 82,080 and 43,200 B. T. U. respectively; hence, when a sufficient excess of manganese is present all the sulphur will be found in combination with it. Theoretically, each part of sulphur requires 1.7 parts of manganese to fix it in the form of MnS, but practically, owing to the operation of the mass law, a considerable excess of manganese is necessary, usually from three to five parts for each part of sulphur.

It is well known that sulphur has a greater tendency to segregate than any other constituent of cast iron (21, 31, 132), but this segregation is much greater when it is present as MnS than when present as FeS. This is readily understood when we remember that FeS is soluble in the molten solution while MnS is insoluble. FeS, therefore, is prevented from segregating through the process of diffusion as long as the metal is in the molten state. It is only during the period of freezing that it is set free and then its segregation through the action of gravity is greatly hindered.

Manganese sulphide, on the other hand, is insoluble in the molten metal and there is nothing to prevent its floating towards the top under the action of gravity, and thus segregating in the upper portion of the pig or casting. Since the

difference in specific gravity between iron and manganese sulphide is not great the molten metal must remain in a quiet state for a considerable time to get anything like a perfect separation of the sulphur. Where this condition can be met, however, and the surface of the metal remains molten much of the sulphur may be entirely eliminated through oxidation at the surface.

Because of the great tendency of sulphur to segregate much care must be used in the sampling of cast iron. In pig iron the sulphur in the top of the pig is not infrequently two or three times as great as in the lower part, and it is manifestly unsafe to take drillings from one hole only unless that hole be drilled clear through the pig from top to bottom.

Silicon and sulphur are opposed to each other in their action on the carbon of cast iron, *i.e.*, sulphur tends to cause the retention of the carbon in the combined or solution form and to prevent its precipitation as graphite.

Upton explains the effects of sulphur on the carbon of cast iron as follows (73, pp. 398, 404):

"Carbon displaces sulphur from solution in the iron and the sulphur then goes into the form of *FeS*. But the sulphur in the *FeS* uses up iron which might otherwise be caring for carbon and so there results an increased concentration of carbon in that part of the iron which remains uncombined with sulphur, and hence, in a cast iron saturated with respect to solution carbon, a precipitation of .05% graphite for each 1% sulphur. On the other hand sulphur decreases the solvent power of molten iron for carbon, or in other words, the carbon content of the liquid eutectic, by .3% for each 1% of sulphur. Hence, the net effect of sulphur is to decrease the graphite by .3—.05 = .25% for each 1% of sulphur, to decrease the total carbon by .3% for each 1% sulphur, and to decrease the combined carbon by .05% for each 1% sulphur."

This theory does not seem to fit in very well with the results of practical experience, since, as is well known, very small

amounts of sulphur have a much greater effect in lessening graphite than is indicated here. Moreover, an increase in sulphur usually results not merely in a decrease in total carbon and graphite, but in a decided increase in combined carbon (see p. 50). This may, however, be explained by the work of Levy (100), who finds that the action of sulphur in increasing combined carbon is physical rather than chemical. This being true sulphur may act as stated by Upton and still have the great hardening effect which is noted in practice.

It is probable that it is only sulphur in the form of *FeS* which affects the condition of carbon according to the preceding dicussion; at least, it is certain that *MnS* has a very much less effect probably on account of its insolubility in the molten metal. This makes it very necessary to take into account the amount of manganese present when considering the influence of sulphur.

It has been stated that the presence of much silicon decreases the amount of sulphur which cast iron can take up, and Turner (46) has plotted a curve showing the relation of silicon percentage to maximum sulphur found in Cleveland (England) pig iron. It is probable, however, that the per cent. of manganese has a decided influence on this relation, and there is no theoretical reason why we should not have an indefinite amount of sulphide suspended or emulsified in cast iron. It is not uncommon at the "blowing in" of blast furnaces to make iron containing from four to five per cent. silicon and as much as .2% sulphur, and Wust and Schuller (82) succeeded in preparing samples containing 3% sulphur together with 6% silicon. They state, however, that with 20% silicon all of the sulphur was eliminated as the volatile compound *SiS*.

Wust and Schuller also found that the presence of sulphur reduced the total carbon. Its effect in this way is inappreciable in the small percentages in which it occurs in ordinary cast iron, but an artificially prepared sample containing 26% sulphur could take up only .17% carbon, and when a highly carburized iron was melted with iron sulphide

two layers were formed, the lower of which was high in carbon and relatively low in sulphur, while the upper was low in carbon and high in sulphur.

The effects of sulphur on the physical properties of cast iron may be summed up as follows: Through the formation of the iron sulphide eutectic films it causes brittleness and weakness especially to shock. Through its action on the carbon it increases hardness and may either increase or decrease the strength according as the combined carbon was already too low or too high. It has a great tendency to cause blowholes especially near the upper surface of thick castings. So marked is this effect in pig iron that high sulphur pig may nearly always be spotted by the presence of blowholes in the top surfaces. Sulphur probably has a more detrimental effect on the low silicon, or chill iron, than on the ordinary foundry grades (34). All of these effects of sulphur are considerably lessened by the presence of sufficient manganese to insure its being in the form of MnS, but on the other hand, the segregation of MnS may cause bad places in the casting apparently due to "dirty iron."

MANGANESE

Manganese may exist in cast iron in two forms. One form, manganese sulphide, we have already considered, the other is manganese carbide, or manganiferrous cementite.

In the carbide form manganese has usually been considered as replacing part of the iron in cementite and forming a mixed carbide of the form $(MnFe)_3C$. If we accept Upton's theory of the constitution of cast iron cementite is not present, hence manganiferous cementite would also be unlikely. According to Upton (73, p. 398):

". . . Manganese acts in the alloy like a more active variety of iron; as manganese can take care of more carbon

in solution than iron can, addition of small amounts of manganese increases the solution carbon and decreases the graphite."

". . . One per cent. manganese would decrease graphite by 0.03%. . . . If the manganese forms Mn_3P or MnS we still have, on account of the difference of atomic weights of manganese and iron, a given weight percentage of manganese in the alloy more affective than the same weight percentage of iron in the ratio 55.9 to 54.9 or 2% better. Therefore so far as displacing power in manganese is concerned it makes no appreciable difference what the manganese does in the alloy; all of its possible actions lead to the same value of displacing power. . . ."

Since manganese increases slightly the carbon content of the eutectic the total carbon is raised .03% for each 1% manganese.

This explanation does not seem to explain satisfactorily all the facts noted in practice. For example, the presence of small gritty particles (usually assumed to be manganese carbide) in high manganese, high silicon iron, the undoubted presence of Mn_3C in ferro manganese, and the fact that after the sulphur is neutralized the percentage of combined carbon is increased very rapidly by the addition of manganese. We prefer, therefore, to retain as a working basis, the theory that manganese does form carbide, Mn_3C, this carbide separating at some temperature below the freezing point of iron, and reducing the graphite by the amount of carbon which it holds in the combined state.

Wust has investigated the alloys of iron-carbon-manganese and his results show, first, that manganese in commercial quantities has practically no effect on the melting point or composition of the iron-carbon eutectic. Second, that manganese exerts a strong brake action on the *gamma* to *alpha* transformation on the line *YT*. This is shown by the fact that the halting point corresponding to this transformation is lower by the addition of manganese (2% manganese lowers it 54° F., or from 1335 to 1281° F.) while with 5% manganese it disappears alto-

gether. This fact makes it very probable that a large part of the hardening effect of manganese is due, not to the increase in combined carbon, but to the incomplete change of the *gamma* and *beta* ferrite to the *alpha* form.

Apparently, sulphur has a greater affinity for manganese than has carbon, hence, in the presence of much sulphur and little manganese that little will be practically all combined with the sulphur. As the manganese is increased and the sulphur becomes nearly satisfied manganese carbide appears, and after the sulphur is entirely neutralized all additional manganese goes into the form of carbide.

Manganese, besides neutralizing sulphur, also has a beneficial action in that it may under proper conditions remove dissolved oxide. This it does because of its greater affinity for oxygen (the molecular heat of formation of *MnO* is 163,620 B. T. U. as compared with 118,260 B. T. U. the molecular heat of formation of *FeO*) and because the *MnO* which forms is insoluble in the metal and hence, if sufficient time be given, floats out and passes into the slag. The temperature of the cupola is seldom high enough to get the full benefit of this reaction, but it is probably important in the blast furnace resulting in a purer and stronger pig iron.

COPPER

Small traces of copper are found in a great many pig irons and considerable amounts in some few brands. Campbell (113) out of nine brands of American pig iron found in seven of them copper in amounts ranging from .011% to .169%. Pig iron made from the Cornwall, Pa. magnetic ore contains from .75% to 1.0% copper; that made from some Cuban ores contains about .1%; and several Virginia brands contain appreciable quantities (168, p. 472).

The effects of copper upon steel have been the subject of much research and discussion and as a result, its effects here are quite well understood. There is, however, but little data as to its action in cast iron.

Copper alloys with pure iron in all proportions, forming with it a solid solution up to 3.5% copper while beyond this the alloys are eutectiferous. The transformation points of iron are but little affected by the presence of small amounts of copper, the melting point being slightly lowered and the *gamma* to *alpha* transformation point also somewhat lowered. In steel, copper increases the fluidity, hardness and tensile strength and decreases the ductility and ease of forging. It also seems to have a marked effect in increasing the resistance to rusting and corrosion.

Iron saturated with carbon will take up only about 5% of copper, and this then, is the maximum possible in cast iron. Lepin (92) found that 4.9% copper increased the tensile strength of cast iron by about 15% and that castings containing a high proportion of copper can be made perfectly sound and good. It has been stated that the presence of copper in cast iron increases its resistance to corrosion.

Copper has a greater affinity than iron for sulphur and when present in iron the sulphur is probably in the form of a binary eutectic of Cu_2S and FeS (or ternary eutectic of Fe-Cu-S), having a melting point of about 1600°F. (155) or about 180° lower than the Fe-FeS eutectic. This is probably the reason why the presence of copper accentuates the red shortness due to sulphur.

The presence of copper has one effect which is of importance to the analytical chemist; that is, its action in preventing the complete evolution of sulphur in the ordinary method of sulphur determination. This makes it necessary to frequently check sulphur analysis by gravimetric methods in the case of irons which are known to contain copper.

NICKEL

Nickel occurs in traces in many American pig irons and Campbell (113) found from a trace to .072% in six out of nine American brands which he examined. Occasionally,

larger quantities are found and a ferro-nickel pig containing a high percentage of nickel is made in certain foreign localities, but is not used for foundry work.

The chief effect of nickel in iron is to lower the temperature at which the *gamma* to *alpha* transformation on the line *YT* takes place, and this is true in cast iron as well as in steel. Another effect of nickel when present in large amounts is to cause separation of carbon in the form of graphite. Because of its action in retarding the change of the iron from the hard *gamma* to the soft *alpha* state nickel in quantities of 5% and upwards has a strong hardening effect while at the same time graphite is precipitated and the iron will be gray. Several experimenters have found that the addition of nickel to low silicon irons lessens its ability to chill and that a sufficient amount added to white iron will make it gray. (101, 106, 107, 193.)

It has been noted (121) that the presence of less than 1% of nickel in either cast iron or steel seems to produce a detrimental effect. Larger amounts greatly strengthen steel. The effect of nickel on the strength of cast iron has been recently investigated by Webb (45) and his results are summarized as follows:

% Nickel	Transverse Strength	Deflection	Modulus of Rupture
—	2746	.09	42905
.67	2985	.10	47195
1.18	2665	.09	41585
2.07	2845	.095	43890
3.25	3070	.09	48520
6.65	2420	.085	39580

The iron used contained 2.10% silicon, .09% sulphur, .62% phosphorus and .45% manganese. Another series of experiments quoted by Browne (121) is as follows:

% Nickel	Transverse Strength
—	4530
.75	4400
1.00	4175
2.00	4800
3.00	5200

The iron used was No. 2 charcoal pig.

These results, while somewhat discordant, at least show that the effects of nickel upon strength and ductility are relatively unimportant. It is stated that nickel produces an excellent effect on the grain and appearance of the metal and renders it capable of taking a high polish. Its high cost in connection with the relatively small benefits to be derived from its use will probably prevent, at least for the present, its commercial use in cast iron.

OXYGEN

The possibility of the presence of oxygen in a highly carburized metal like cast iron has been the subject of much argument and dispute during the past few years. The weight of evidence, however, seems to indicate the frequent presence in cast iron of something which produces very marked and disagreeable effects, which acts like oxygen, and which might as well be called by that name as any other until we have more definite information as to its identity.

The effects of oxygen, as we shall continue to call it, are as follows: first, it decreases the fluidity of the molten metal and apparently raises its melting point so that skulled ladles and short-poured castings accompany its presence; second, it renders the iron very weak and brittle; third, it is apt to cause blowholes, porosity, dirty places and other forms of unsoundness; fourth, it slightly increases the hardness of the iron.

White iron is probably more liable than gray to this trouble. By some it is thought that the variable quality

of different brands of iron which are otherwise of the same chemical composition may be accounted for by the presence or absence of traces of oxygen. According to this theory cold-blast charcoal, hot-blast charcoal, and coke iron would contain increasing amounts of oxygen in the order named. There would also be differences in the irons belonging to each of these classes, depending on the relative reducibility of the ores from which they were made, the rates at which the furnaces were blown, etc. There are a number of well known facts which lend a color of probability to this theory. For example, it is well known that the use of mill cinder, which is a material very difficult to reduce, gives a very poor quality of iron. Again, in those sections of the country where iron is made from brown hematite ores known to be very readily reducible, the brands of iron made have, almost without exception, achieved a high reputation for strength and desirability. Still another example mentioned by Dr. Moldenke (169) is the difference in quality between malleable Bessemer iron which is made in a lightly blown furnace and regular Bessemer of the same composition, but made in a furnace which is driven to the limit. It is probable that trouble from oxidized metal comes most frequently from bad cupola practice, the oxygen being absorbed during the melting (170).

Fortunately, it is possible to eliminate dissolved oxide from molten cast iron by the use of deoxidizing agents. The substances which have been proposed as deoxidizers and their heats of combination per pound atom of oxygen are as follows:

Titanium	TiO_2	?	
Vanadium	Vd_2O_5	?	
Magnesium	MgO	258,120	B. T. U.
Calcium	CaO	236,700	"
Aluminum	Al_2O_3	235,560	"
Carbon	CO or CO_2	52,560 to 174,960	"
Sodium	Na_2O	181,620	"
Manganese	MnO	163,620	"
Silicon	SiO_2	162,000	"

These may be compared with the heat of formation of iron oxide (FeO)—118,260 B. T. U. per pound atom of oxygen.

Of these elements titanium, vanadium, aluminum, manganese, and silicon are sometimes used in practice for the purpose of deoxidizing cast iron. Titanium and vanadium seem to be particularly efficient in this respect and are gradually coming into extended use (see p. 76). Aluminum would also appear from the above table to be highly efficient but owing to certain disadvantages has not proven very successful in the case of cast iron (see p. 73).

Silicon, while not standing very high, in the above list, does seem to help considerably when added to the ladle as high grade ferro silicon, and this even though the iron may already contain 2% or over of silicon (35, 20). This peculiar fact may, perhaps, be explained as follows: The silicon in the ferrosilicon will be chiefly in the form of $FeSi$ while that in the iron is in the form of Fe_2Si. It is quite conceivable that the silicon in the first named compound might be much more active than that in the second, and especially at the instant when it dissolves in the iron and is converted into Fe_2Si. The presence of silicon is probably the reason why gray pig iron is less liable to oxidation troubles than white.

Manganese is a highly efficient deoxidizer at high temperatures and is largely used for this purpose in steel making. At lower temperatures its affinity for oxygen is lessened, and hence, its full benefit is not secured when it is added to the cupola mixture or to the ladle. If steel scrap be used the higher melting point of semi-steel makes the manganese more effective. The temperature of the blast furnace is high enough to allow manganese to do its best work in this line, and hence we find that high manganese irons are apt to be strong and, conversely, strong irons are apt to be high in manganese.

Carbon does not seem to remove traces of oxygen from iron very efficiently under foundry conditions, but that it has some effect is evident from the fact that steel and semi-

steel are more liable to oxidation troubles than ordinary cast iron.

NITROGEN

The effects of nitrogen on iron are very obscure and practically all of our knowledge on the subject is due to Braune (43). According to this investigator the effects of nitrogen on the physical properties of steel are very serious, as little as .035% causing a great loss in tensile strength, reducing the ductility nearly to zero and causing the formation of hardening cracks.

Its effects on cast iron were not studied in as much detail but it seems that they would probably be serious if it were present in any considerable quantity. It was found that gray pig iron is ordinarily nearly free from nitrogen, coke irons of this class showing .007—.009%. White iron usually contains much more, sometimes as high as .035%. In chilled cast iron the presence of nitrogen is shown quite clearly by the fracture of the metal. "In ordinary chilled pieces the boundary between the gray and white is sharp, and if blowholes are present they are in the white part, with rounded sides; as the nitrogen content increases, the boundary between the two colors becomes less and less distinct, white patches become common in the gray part, and vice versa, and small gas cavities appear in the gray part, with sharp corners. Braune could not determine any characteristic change caused by small amounts of nitrogen in the appearance of either white, gray, or puddled iron. But 0.03 to 0.045% of nitrogen will cause the small gas cavities referred to in white iron, and enough nitrogen to cause brittleness will give a crystalline fracture, with bright reflections to soft iron." (43)

As a matter of fact, it is doubtful if nitrogen is ever an important factor in gray cast iron although it may possibly be in white. Gayley (44) describes some tests which were

made on the nitrogen content of various grades of pig iron and found that there was apparently no relation between the amount of nitrogen and the quality.

Nitrogen appears to be present in iron as a nitride, probably Fe_5N_2. It can be eliminated from molten iron by the addition of titanium, for which it has a remarkably strong affinity and with which it combines to form titanium nitride, TiN. This is insoluble in molten iron and hence, passes out into the slag. Several other elements, notably magnesium and boron, may also possibly serve to eliminate nitrogen, but none of them act as energetically as titanium.

ALUMINUM

Aluminum is never found in pig iron in more than the merest traces but it is sometimes added to remelted cast iron before pouring in the mold. Its effects were first systematically studied by Keep, Mabery, and Vorce (86), and their results may be summarized as follows:

First—As to the solidity of the castings, they found that the addition of aluminum caused a finer grain, increased solidity and freedom from blowholes. Only a few tenths per cent. of aluminum were necessary to secure these results.

Second—To test the question as to whether the aluminum remains in iron and exerts an influence when the iron is remelted, they found that a white iron containing .25% aluminum after remelting six times, with fresh additions of iron each time, still contained traces of aluminum and remained of superior quality.

Third—As to the effects of aluminum on the grain. It is stated that aluminum seems to enable cast iron to hold in solution all of its carbon until just at the point of solidifying, when this carbon is precipitated as very finely divided graphite. This results in a uniform structure, no pockets of

graphite and greater strength. The rapidity of cooling was found to make but little difference as the release of carbon is instantaneous and only at the instant of crystallization. It was found that .25% aluminum was sufficient to slightly darken the fracture of white iron, while .75% would precipitate enough graphite to make it quite gray.

Fourth—With regard to its effects on the tendency to chill, it was found that the presence of aluminum caused the casting to be unaffected by the chilling, the graphite being liberated whether the cooling was slow or rapid.

Fifth—It was found that aluminum had a tendency to prevent the sand burning to the iron. This because it separated graphite which seemed to act as a facing.

Sixth—The effects of aluminum on hardness appear to be much the same as that of silicon except that it is stated that the increased fineness of grain enables the casting to be more readily machined.

Seventh—With regard to static strength, the presence of aluminum was found to increase the strength, but there is no close relationship between this increase and the percentage of aluminum.

Eighth—The resistance to impact, or the dynamic strength, was increased by the presence of small amounts of aluminum to an even greater degree than the static strength. This increase was greater in the case of white iron than gray, and with more than a certain percentage of aluminum, fell off again.

Ninth—It was found that aluminum improved the elasticity.

Tenth—It was found that aluminum decreased the amount of permanent set as compared with iron equally soft by the use of silicon. This is probably because of the increased

fineness of grain and compactness in the aluminum treated castings.

Eleventh—The shrinkage was found to be slightly increased by small quantities of aluminum, probably due to the elimination of all blowholes. With .75% and upwards, of aluminum the shrinkage was decreased especially on white iron.

Twelfth—It was found that the fluidity was slightly increased in the case of white iron through the addition of aluminum. In the case of gray iron the results were uncertain.

Other investigators who have since worked on this same subject have for the most part corroborated these results (87, 88, 89). It has been found, however, that the effect of aluminum in increasing strength is limited to very small quantities, say, under 1%, and is probably due entirely to its deoxidizing power. Also that the action of aluminum on the condition of the carbon in the iron is reversed in the case of quantities greater than 1 or 2%. That is, high aluminum tends to decrease the graphite and cause the carbon to take the combined state. The amount of carbon which can be retained in iron is slightly lessened by the presence of large amounts of aluminum. For example, when 12% of aluminum were added to cast iron the carbon was reduced to 3.15% and was all in the combined state. When more than 1% of aluminum is added to cast iron the molten metal becomes very sluggish and difficult to pour properly. This is because the film of aluminum oxide forms on the surface of the molten metal and offers resistance to its flow.

TITANIUM

Titanium is a common constituent of iron ores but owing to the fact that it is very difficult to reduce from the oxide it is rarely found in quantities of more than one or two tenths

per cent. in pig iron. It is, however, made in the form of a rich ferro alloy containing from 5 to 25% titanium in the electric furnace. The 10% titanium alloy is the one which is generally made.

These alloys have found a certain use in the treatment of cast iron and steel and their use would no doubt be much more extensive were it not for the difficulty of dissolving them in the molten iron. Titanium is an extremely infusible metal, its melting point being estimated to be about 4500° F. Its addition to iron in any considerable quantity raises the melting point of the iron, and hence, we find that the ferro titanium alloys are quite difficult to melt and dissolve. The alloy which is made by reduction with carbon and hence contains several per cent. carbon is more readily melted than that made by reduction with aluminum and which is free from carbon.

Titanium may be added to cast iron in three ways: first, as ferro titanium (either the carburized or non-carburized alloy), in the top of the cupola with the iron as charged. Added in this way, there is no difficulty in getting thorough solution, but there is considerable waste of titanium in the melting (through oxidation), and a bull ladle of capacity at least equal to weight of charge used is essential in order to get a uniform distribution of titanium.

Second, as ferro titanium (either the carburized or non-carburized alloy, preferably the former) to the molten metal in the ladle. The great objection to this method is the difficulty of getting the alloy to melt and dissolve in the iron. To secure good results the finely crushed alloy should be preheated to redness before being added to the iron, or it should be added to the iron as it flows down the cupola spout, the fall into the ladle serving to carry it under the surface of the metal. Good, hot iron is essential in either case. Careful foundrymen who are willing to take the necessary pains may obtain excellent results by using ferro titanium in this way.

Third, as titanium thermite. This is a mixture of titanium oxide, iron oxide and powdered aluminum contained in a tin can. When it is plunged into a ladle of molten iron, reactions occur which result in the formation of metallic titanium and iron and the heat of reaction is so great that these products are produced in the molten state and at once alloy with the metal. It is an ideal method of adding titanium to the iron since there is no danger of chilling the iron, perfect solution is obtained and the process is so simple that it can be carried out by any laborer and without disturbing in any way the regular foundry routine. Because of these advantages it is quite extensively used in spite of its high cost which is considerably more than either of the ferro titanium alloys (116, 117).

The action of titanium is probably due almost entirely to its very energetic chemical affinity for the gases oxygen and nitrogen. By removing the traces of these gases which are dissolved in cast iron the metal is often greatly improved in quality.

Of the many experiments on the use of titanium in cast iron which have been carried out in the last few years, by far the most complete and convincing are those of Dr. Moldenke (110). The results of his experiments on the effect of titanium on the strength of iron are summarized as follows:

TABLE III

EFFECT OF TITANIUM ON THE STRENGTH OF CAST IRON

	Gray		*White*	
Original Iron	(9 tests)	2020 lbs.	(8 tests)	2050 lbs.
plus .05% Ti.	4 "	3100	11 "	2400
plus .10% "	3 "	3030		
plus .05% " & Carbon	6 "	3070	9 "	2420
plus .10% " & "	6 "	2990	10 "	2400
plus .15% " & "	4 "	3190	10 "	2520
Average titanium treated iron		3070 lbs.		2430 lbs.
Increase in strength over original		52%		18%

It is worthy of note that additions of titanium beyond .05% appear to have no further result, and this would seem

to indicate that the improvement affected by titanium is due entirely to its scavenging or purifying action and not to the presence of the element in the metal.

The presence of titanium in gray cast iron appears to have no effect upon its hardness, shrinkage or other properties besides strength. On white cast iron, however, it has the effect of lessening somewhat the depth of the chill and of making the chill that remains very much harder. Dr. Moldenke gives the following results: Test pieces made with iron which chilled 1½ inches deep, after treatment with titanium in the ladle gave but 1 inch chill. Prisms were cut from the chilled portion of these test pieces and tested for crushing strength and for hardness. The original iron crushed at 173,000 lbs. per sq. in. and stood 445 in the test for hardness; the treated piece had a crushing strength of 298,000 lbs. per sq. in. and showed a hardness of 557. The soft metal back of the chilled portion had practically the same hardness in both cases. An example of the very superior wearing qualities of car wheels made from titanium treated cast iron is given by Slocum (109).

Many other examples showing the great improvement in quality caused by the addition of titanium to cast iron might be quoted (108, 109, 110, 116, 117). The preceding, however, are sufficient to prove the case and it only remains to summarize the effects of titanium.

The addition of small amounts of titanium will, through its purifying action, increase the strength of cast iron from 5 to 50%, depending on the initial quality of the iron. That is, a much greater improvement will be effected in the case of poor material than in the case of an iron which is already of excellent quality. .05% titanium, corresponding to ½ lb. of the 10% alloy per 100 lbs. of metal, is enough to produce these effects on any ordinary iron; somewhat more may occasionally be needed in the case of badly oxidized metal. Using these small amounts the titanium passes into the slag carrying with it the oxygen or nitrogen and little or none would ordinarily remain in the iron. When amounts of 1% or

upwards of titanium are added to cast iron the metal becomes exceedingly tough, strong and to a certain degree malleable. Titanium is an excellent preventative of blowholes and promotes soundness in iron to which it is added. In the quantities in which it would be ordinarily used it seems to have no effect whatever upon the condition of the carbons or upon the hardness of iron except in the case of chilled iron as previously mentioned.

VANADIUM

Vanadium never occurs in pig iron in other than the merest traces. It can, however, be procured as a ferro-vanadium alloy containing from 10 to 40% vanadium, or as an iron-vanadium-silicon alloy and could readily be added to the metal in remelting if this were found desirable. Since vanadium has a very high melting point much the same difficulties are found in adding it to cast iron as in the case of titanium. The 30% alloy has the lowest melting point but the addition of silicon makes it more readily soluble in molten iron and hence the iron-vanadium-silicon alloy seems the best adapted for use with cast iron.

Vanadium has been found to confer very valuable properties to steel and has been repeatedly suggested as an addition to cast iron. About the only exact data concerning its effect on cast iron are due to the investigations of Dr. Moldenke (123) whose results are summarized in the following table:

TABLE IV

EFFECTS OF VANADIUM ON THE TRANSVERSE STRENGTH OF CAST IRON

	Burnt Iron Gray	*Burnt Iron White*	*Machinery Iron, Gray*	*Remelted Car Wheels*
Original Iron, no Vd.	1310	1440	1980	1470
plus .05 Vd.	2220	1910	1980	3020
plus .10 Vd.			2373	2800
plus .15 Vd.			2360	2950
.50% Mn. no Vd.			1970	2790
.50% Mn. .05% Vd.			2130	2970
.50% Mn. .10% Vd.			2530	3030
.50% Mn. .15% Vd.				3920

The vanadium alloy used in these experiments contained, vanadium 14.67%, carbon 6.36%, silicon 0.1% and was added in the powdered form to the molten metal in the ladle. In some cases ferro manganese was first added in order to effect a preliminary oxidation. The test bars were 1¼ inches diameter and were tested 12 inches between supports.

Besides the increase in static strength which is shown by these tests, it is thought that vanadium increases in even greater degree the dynamic strength, rigidity and resistance to wear. It is well known that this element produces such effects on steel but there is no very definite data concerning its action in this respect upon cast iron. It will be noted that the improvement in white iron is much greater than in gray iron, and it is claimed by a leading roll manufacturer that vanadium increases to a wonderful degree the strength, wearing qualities, and life of chilled rolls.

The action of vanadium upon iron and steel appears to be due largely to its powerful deoxidizing action. It is, however, a strengthener in itself through the formation of a tough, solid solution of vanadium in ferrite and through its tendency to decrease the size of the ferrite grains. In the case of steel it tends to cause the formation of sorbite rather than pearlite (165), but it is not known whether this also applies to cast iron.

PART II

THE PROPERTIES OF CAST IRON

There are many physical properties which are, or may be, of importance in iron castings. A list of the more important is as follows:

Static strength, including
- Tensile strength,
- Compressive strength,
- Transverse strength,
- Torsional strength,
- Shearing strength.

Dynamic strength, embracing
- Resistance to repeated stress,
- Resistance to alternating stresses,
- Resistance to shock.

Elastic properties, embracing
- Elastic limit,
- Resilience or elasticity,
- Rigidity,
- Toughness,
- Malleability.

Hardness, embracing
- Hardness of mass,
- Ability to chill,
- Hardness of chill.

Grain structure, including
- Fracture or grain size,
- Porosity,
- Specific gravity.

Shrinkage, embracing
- Shrinkage of the liquid mass,
- Shrinkage of the solid mass,
- Stretch.

Fluid properties, embracing
- Fusibility,
- Fluidity.

Resistance to heat, embracing
Resistance to continued heat,
Resistance to alternate heating and cooling,
Resistance to very low temperatures.

Electrical properties, including
Electrical conductivity,
Magnetic permeability,
Hysteresis.

Miscellaneous properties, including
Resistance to various corrosive agencies,
Resistance to wear,
Co-efficient of friction.

In addition to this list which gives the properties of the metal substance, the following properties of the mass as a whole are important:

Soundness, or freedom from blowholes and shrinkage cavities.
Cleanness, or freedom from inclusions of dross, etc.
Freedom from pinholes and porous places.
Homogeneity, or lack of segregation.
Crystallization.
Freedom from shrinkage strains.
Tendency to peel off sand and scale.

We will now consider, one by one, each of these properties in relation to chemical composition in every case where any relation is known.

———

STRENGTH

Although in our table we have enumerated several different kinds of strength, we now find it convenient to treat the subject in general.

As regards chemical composition there are nine factors which influence strength of cast iron: 1—per cent. graphite; 2—size of individual graphite flakes; 3—per cent combined carbon; 4—size of primary crystals of solid solution *Fe-C-Si*;

5—amount of dissolved oxide; 6—per cent phosphorus; 7—per cent sulphur; 8—per cent silicon; 9—per cent manganese.

In addition to these factors there are probably some others which influence strength, since we not infrequently find considerable variations which cannot well be attributed to any of the above, unless possibly to number 5.

1. *Per cent graphite.*—The weakening effect of graphite is due to its own extreme softness and weakness, and to the fact that it occurs in small flakes or plates and hence affords a multitude of cleavage planes through the metal. The size of the graphite particles is evidently important as well as the amount but this factor will be discussed under another head. The factors which influence the amount of graphite and their quantitative effect have been thoroughly discussed in Part I, pages 45 to 48, and it only remains now to state their use in controlling graphite in the practical work of the foundry.

Theoretically, the simplest method of decreasing graphite is to lower the silicon, each decrease on 1% in silicon lessening the graphite by .45%, provided the total carbon remains the same. Practically, however, the fact that all the carbon not graphite becomes combined is an important objection, for when we lower the silicon too much the resulting increase in combined carbon increases the hardness and, beyond a certain point, decreases the strength. The minimum permissible silicon will depend chiefly on the hardness allowable.

The same objection applies to decreasing the graphite by increasing the sulphur and manganese, and in the case of sulphur there is also the objection that its direct effects are injurious. The rate of cooling is, of course, beyond the control of the foundryman in the majority of cases, while even if it were not the graphite could not be reduced by rapid cooling without a corresponding increase in combined carbon.

Coming finally to the total carbon, we find here a means

of reducing graphite without in any way affecting carbon, and hence, hardness. The only limitation to this is that as total carbon and graphite are reduced, shrinkage is increased and the metal becomes more liable to oxidation, blowholes and other defects.

There are three ways of reducing total carbon in castings; first, by the use of low carbon pig iron; second, by melting in the air furnace; third, by the use of steel scrap in the cupola mixture.

The pig irons lowest in total carbon are, as a class, the charcoal irons, especially those made with cold blast, and these irons are also, as a class, the strongest, although not entirely because of their total carbon. To get the full benefit of this iron, it should be melted in the air furnace, but with careful attention to details very good results may be obtained in the cupola also.

In air furnace melting it is easy to reduce total carbon to almost any figure within reason. 2.75% is commonly obtained in melting for malleable castings. Of course the silicon is also burnt out during this process, but were it desired, this could be readily replaced by suitable additions of ferrosilicon. From the standpoint of quality the air furnace is certainly the ideal method of melting, and hence, we find that many lines of castings which must be of particularly high quality are invariably made from air furnace metal.

The addition of steel scrap to the cupola has now become common practice, the product obtained being known as semi-steel and differing chemically from ordinary cast iron only in being somewhat lower in total carbon and graphite. Physically, the metal so made is characterized by greater strength and total shrinkage, hardness remaining about the same. While the process of making a superior metal from a mixture of cast iron and steel has been known for a long time, dating back to Sterling's patents in 1846 (16 and 131, p. 219), there are still many who hold that a satisfactory semi-steel cannot be made by melting in a cupola. Certainly there are

many difficulties in making it in this way but the success with which it is done shows that these are not insurmountable.

The chief points to be watched in melting steel scrap in the cupola mixture are as follows:

Trouble with blowholes. This is due to the fact that semi-steel being lower in carbon oxidizes more readily than cast iron. The trouble may usually be overcome by correct cupola practice and the use of ferro-manganese or other deoxidizers in the ladle. Owing to the higher melting point of semi-steel mixtures ferro-manganese is much more efficient as a deoxidizer here than in the case of cast iron. It is said that wrought iron scrap is the frequent cause of porosity in castings, possibly because of the considerable amounts of iron oxide which it contains in the form of slag fibers.

High shrinkage. This is due to the decrease in graphite and is hence inevitable. On work where this is an important factor a proper balance must be struck between shrinkage and strength. See also under "Shrinkage," page 107.

Imperfect mixture of steel and iron resulting in irregular quality of casting, hard spots, etc. This results from the higher melting point of steel and consequent difficulty of getting perfect solution in the cast iron. It may be largely overcome by careful attention to the charging of the cupola, placing the steel scrap on the coke and the iron on top of the steel (so that the steel will reach the melting zone first and the molten pig will run down over the heated steel instead of away from it as would happen if the order were reversed). A large receiving ladle should, of course, be used also. Another point to be observed is in regard to the size of the steel scrap. Too large scrap is difficult to melt, but, on the other hand, very small scrap is also objectionable as being an abundant source of hard spots in the castings. Apparently very small pieces of steel are liable to be washed down through the coke bed and out of the cupola spout without being completely melted. Finally, it is said that high carbon steel is much more difficult to melt and alloy with cast iron than low

carbon material. This is exactly contrary to what we should expect from theory, but is so confidently maintained by competent foundrymen who have made the experiment that it is thought best to call attention to it here.

Non-improvement in the strength of the castings due to absorption of carbon in the cupola. Of course a metal non-saturated with carbon when melted in contact with coke as in the cupola will take up carbon, tending, if time be allowed, to become saturated. It has been urged, therefore, that the melting of steel in the cupola nullifies all the advantages of the use of this mixture (171, p. 343). This criticism is only partly true however, for under suitable conditions of cupola practice only a comparatively small amount of carbon will be taken up by the steel and the total carbon in the resulting molten metal will be materially lowered. To accomplish this end the tuyeres should be low and the iron allowed to run from the cupola spout as fast as melted. While it is advisable to use enough coke to get a good, hot metal, still, the less excess above that amount the better from the standpoint of carbon absorption (94).

Regarding the amount of steel scrap to use it has been found by trial that the best results are obtainable with about 25%. Increase to 33⅓% caused a slight falling off in strength (15). Probably these figures would not hold for every condition of practice but, in general, 20 to 30% steel is a sufficient amount to give the maximum results.

2. *Size of graphite flakes.*—The size of the graphite flakes is probably the most important factor of all those which influence strength and is the one which most frequently upsets our calculations as to the relation between chemical composition and strength. The fact that this factor is one to be considered has been appreciated in a general way for a long time, whence the so frequently used expression "close-grained, strong iron." Recently, however, Mr. F. J. Cook and G. Hailstone (11) have brought out in a striking manner the great difference in irons in this respect. They give data showing that of two mixtures practically identical in com-

position the one was invariably much lower in strength (usually about one-half) than the other, this being the case for a great many heats extending over a long period of time. The following analyses and tests are given as typical of the series:

Series	*A*	*B*
Tensile test	9.1 tons per sq. in.	18.3 tons per sq. in.
Total carbon	3.250	3.092
Graphitic carbon	2.397	2.289
Combined carbon	0.853	0.903
Silicon	1.328	1.314
Sulphur	0.095	0.101
Phosphorus	0.923	0.909
Manganese	0.290	0.335
Iron by difference	94.114	94.149

Messrs. Cook and Hailstone have investigated and compared the micro-structure of the strong and weak bars and record two interesting facts: first, that the graphite flakes are invariably much larger in the weak bars; second, that when the polished specimens are treated so as to bring out the phosphide eutectic this eutectic is seen to be arranged in the customary heterogeneous manner in the weak bars but in a distinct meshwork structure in the strong iron.

These authors draw the conclusion that it is this meshwork structure which gives great strength to cast iron, but with this conclusion the writer cannot entirely agree. It seems more probable that the increase in strength is caused by the fine state of division of the graphite and that the same influences which have caused this have also caused the meshwork structure.

We may get some idea of the quantitative relationship between strength and size of graphite by considering the relative strength of malleable cast iron and a very open gray cast iron representing the smallest and largest graphite re-

spectively. Malleable cast iron has a tensile strength of 40,000 lbs. and upwards per sq. in., open gray iron about 20,000 lbs. per sq. in. Apparently, then, the increase in the size of the graphite has caused a loss of at least 20,000 lbs. in tensile strength.

It is one thing to find that to get strong iron we must have the graphite in finely divided state and another and much more difficult matter to formulate rules whereby we may secure this desired condition. The writer has given much thought and study to this subject with but indifferent success as far as practical results are concerned. The following discussion, however, is believed to be the first systematic exposition of the subject and may, perhaps, aid others in following it up.

The factors which influence the size of the graphite flakes in cast iron are as follows:

A.—Factors which certainly exert an influence.
- *a.* Rate of cooling.
- *b.* Pouring temperature.

B.—Factors which may possibly exert an influence.
- *c.* Time which iron has remained in the molten state.
- *d.* Presence of dissolved oxide.
- *e.* Presence of steel scrap in the mixture.
- *f.* Mixture of different brands.
- *g.* Nature of ore from which iron is made and treatment in the blast furnace.
- *h.* Per cent metalloids.

a.—The influence of rate of cooling is undoubted, and an example showing its effect on strength and structure is given by Cook and Hailstone (11). We have to distinguish here, however, between the rates of cooling through different ranges of temperature. Evidently the graphite which is separated within the semi-liquid iron will have a much better chance to grow large crystals owing to the greater mobility

of the medium in which it is formed, while that graphite formed within the solid metal will necessarily be in small particles. Hence, we see that it is the rate of cooling through the solidification range 2200° to 2000°F. which is of prime importance, and if we can check the formation of graphite through this range and then allow it to form in the solid metal at lower temperatures we will have all the conditions for both the soft and strong iron. This is the principle of Custer's process of casting in permanent molds and the making of malleable castings is based on the same theory.

b.—The pouring temperature also undoubtedly exerts an influence in the size of the graphite flakes, and hence, on the strength. The relation between them is, however, a matter of some dispute.

Keep (172, p. 174) finds that the coldest poured iron is invariably the strongest. Other investigators have stated that the hottest poured iron is the strongest, while Longmuir (8) finds that iron poured at a medium temperature is stronger than when poured either very hot or very cold. Longmuir's experiments, by the way, are the only ones in which a pyrometer was used and the temperature of pouring measured in degrees. In the other cases the terms "hot" and "cold" are only relative and we have no basis of comparison between the different experiments. For this reason we may place the greatest faith in Longmuir's results.

It is probable that the pouring temperature affects the size of the graphite flakes indirectly through changing the rate of cooling through the solidification range. On this assumption the best results should be obtained from metal poured at as low a temperature as will suffice to give sound castings.

Of the other factors which I have named as probably exerting an influence on the size of the graphite flakes some are undoubtedly important while others may be entirely without effect, but which are which we cannot as yet say cer-

tainly. I can only give the reasons which led me to conclude each factor in the list.

c.—Time which iron has remained in the molten state. This might conceivably have an effect in the case of cast iron high in total carbon, since graphite separating in the liquid metal would remain in the metal if poured at once, and this graphite is in the form of the large flakes known as *kish.*

d.—Presence of dissolved oxide. There is no direct proof that this affects the size of the graphite flakes. However, it is well known that addition of deoxidizing agents almost invariably improves the strength and it is barely possible that a portion of this may be due to change in the size of the graphite.

e.—Presence of steel scrap in the mixture. Although no exact data are at hand it is the common impression that the addition of steel scrap "closes the grain," which is equivalent to saying that it reduces the size of the graphite. It is not improbable that much of the strengthening effect of additions of steel is due to this action rather than to any lowering of the percentage of graphite.

f.—Mixture of irons. It is firmly believed by many foundrymen of the old school that a mixture of brands gives better results than a single brand of the same chemical composition as the average of the mixture. Again, Outerbridge (35) finds that the addition of silicon as ferro-silicon to the ladle increases the strength, whereas, the use of pig containing just that much more silicon would, if anything, decrease the strength. This, he explains by the statement that the ferro-silicon furnishes silicon in the nascent state. However, it is just barely possible that both of these cases might be accounted for by some influence of the mixing of dissimilar metals upon the crystallization of the graphite.

g.—Cook and Hailstone believe that the difference in strength of the two mixtures quoted by them (11) is due to some inherent quality of the pig iron derived from the ores

used or their manner of treatment in the blast furnace. This inherent quality may have some connection with the presence of oxygen or nitrogen in the metal. In the light of our present theories it is quite impossible to account for these differences in any other way, and yet, there may be something else which has thus far remained entirely unsuspected.

h.—Per cent metalloids. This, we know, has a certain effect. For example, high silicon is likely to cause larger graphite as well as more of it. Phosphorus should, theoretically, cause larger graphite since it prolongs the solidification period in which large flakes are free to separate. Whether this is actually the case has not yet been definitely determined. Sulphur and manganese, in the language of the foundry, close the grain, and probably do diminish the size of the graphite as well as its amount.

In conclusion, we are forced to admit that we know very little about this important factor and for the best results must still rely largely upon the accumulated experience of the practical foundryman rather than on the scientific deductions of the metallurgical chemist.

3. *Per cent combined carbon.*—According to Professor Howe (163) the properties of cast iron are the properties of the metallic matrix modified by the presence of the graphite, but since this metallic matrix may be considered as a steel of carbon content equal to the combined carbon of the cast iron, we can predict accurately the effects of combined carbon by the use of the data on steel.

In the case of steel it is found that the strength increases regularly with the carbon up to about .9%, then remains nearly stationary up to about 1.2% above which it falls off slowly.

In the case of cast iron the strength is dependent upon so many factors besides combined carbon that it is almost impossible to determine by direct experiment the percentage of combined carbon giving the maximum strength. All indications, however, are that the highest strength is obtained with some-

where between .7% and 1% combined carbon, which is in sufficiently close accord with the corresponding value for steel. We may therefore state tentatively that the maximum strength is obtained with .9% carbon, all other factors remaining constant.

This applies only to tensile strength (and approximately to transverse). For compressive strength a somewhat higher value, probably about 1.5% combined carbon, would be found to give better results.

4. *Size of primary crystals of solid solution* Fe-C-Si.—There is absolutely no data as to the effect of this factor on the strength of cast iron and it is only from analogy with steel that we give it a place in the list of factors influencing strength. In the case of steel it is well known that the heat or mechanical treatment and consequent size of grain are exceedingly important factors in determining the strength. Whether in cast iron the presence of graphite nullifies these factors or whether they still exert an influence remains to be determined.

5. *Effect of dissolved oxide.*—The influence of oxygen in cast iron has already been discussed to some extent (see Part I, page 69). It is probably a much more important factor than is generally supposed, but there is absolutely no data on which to base a quantitative estimate of its effect.

To reduce oxide in cast iron to the minimum, the following points may be observed:

First, get the best brands of pig iron. It is probable that pig made with charcoal fuel contains less oxygen than that made with coke fuel. Cold blast pig is better than hot blast. Pig iron made from easily reducible brown or carbonate ores is lower in oxygen than the pig made from red hematite or magnetic ores, while iron made from mill cinder should never be used in foundries where strength is a prime consideration. Moreover, a pig iron high in manganese is apt to be comparatively free from oxide because of the de-

oxidizing power of manganese at the high temperature of the blast furnace. It is noteworthy as confirming these observations that most brands of iron which have achieved a reputation for strength are high in manganese and many of them are charcoal irons. The Muirkirk and Salisbury brands which have been known for years as among the strongest irons made in this country answer to every one of these conditions. They are made from readily reducible ores using cold blast and charcoal fuel and contain from 1 to 2% of manganese.

Second, avoid oxidizing conditions in the cupola, particularly high-blast pressures and wrong methods of charging. Dr. Moldenke's system of using small charges is to be highly recommended in this connection (170).

Third, deoxidizing agents may be used, added either to the cupola or to the metal in the ladle. Of the commercially available deoxidizers ferro-titanium, ferro-silicon and ferro-manganese are, perhaps, the most successful, all things considered. Titanium thermite is also extremely valuable in this connection. (See also Part I, under "Titanium" and "Oxygen.")

6. *Per cent phosphorus.*—Phosphorus lessens both the dynamic and static strength but the former more than the latter. It weakens because it forms with iron a hard and brittle compound which has but little resistance to shock. The weakness produced is in nearly direct proportion to the amount of this compound present. The effects of phosphorus on strength do not become marked until upward of 1% is present, but for great strength and particularly strength to shock it should be much lower. Ordinary strong irons may have up to .75%, while iron which is to withstand shock should not exceed .50% and is better even lower. Most "strong" brands of iron are moderately low in phosphorus, for example, Muirkirk contains about .3%.

7. *Per cent sulphur.*—The action of sulphur in decreasing the strength of iron is explained in Part I, page 60, and it is also explained there why it is so much less harmful in the

presence of manganese. Many tests have been made showing that sulphur has no marked effect on strength and many foundrymen will use sulphur to harden iron and close the grain. It is true that an indirect strengthening effect can be obtained through the use of sulphur in some cases, *i.e.*, if too soft an iron is being used the strength will be increased by the addition of any element which will lessen the graphite but the hardening is usually better obtained through decrease in silicon than through increase in sulphur. While increased sulphur may not always show in decreased strength of test bars, yet it is a frequent source of blowholes, dirty iron and the various defects caused by high shrinkage, hence, it often causes an indirect weakness in the iron.

8—9. *Per cent silicon and manganese.*—These elements act chiefly in an indirect manner and because of their effects on the condition of the carbon. Their direct influence in the strength of the metallic matrix is unimportant. From analogy with steel it is probable that silicon in amounts of over 1% causes weakness and brittleness in the metal. Similarly manganese has probably a weakening effect due to its direct action when present in amounts of more than 1.5%.

The preceding discussion is summarized in the following practical rules for making strong castings:

Use strong brands of iron. See pages 68 and 93.
- Charcoal irons if cost will permit.
- Irons made from easily reducible ores.
- Irons high in manganese.

Avoid oxidation in melting.
- Look carefully after the details of cupola practice.
- Avoid oxidized scrap.
- Use deoxidizing agents in ladle if practicable. See pages 70 and 93.

Keep the silicon down as low as possible and still have the necessary softness. About 1.50% will be right for the ordinary run of medium castings. Higher for small castings and lower for heavy ones. With low total carbon high silicon has less effect.

Keep the phosphorus low, especially when sulphur is high. .50% or under is best.

Keep the sulphur low, especially if phosphorus is high. Under .10% is all right for most castings.

Keep the manganese high. 1% for large castings, .7% for medium, .5% for small castings.

Use from 10 to 25% steel scrap in the mixture.

Keep (172, p. 131) recommends using 10% cast iron borings charged in wooden boxes. He states that this is very effective in closing the grain and strengthening the castings.

TABLE V

EXAMPLES OF STRONG IRON

Ref.	Tot. Carb.	Graph.	Comb. Carb.	Silicon	Sul.	Phos.	Mang.	Tensile Str. lbs. per sq. in.
1	3.45			1.14				very high
1	3.20			1.09				very high
7	3.15	2.50	.65	.90			.30	35600
13	3.10	2.70	.40	1.91	.060	.49	.74	31890
15	3.23	2.15	1.08	2.36	.064	.33	.24	31560
15	2.95	2.44	.51	1.83	.100	.65	.55	36860
16	2.18	1.62	.56	1.96	.030	.38	.60	31400
16			.36	1.29	.060	.56	1.00	36400
16			.58	1.50	.070	.47	1.00	34200
16			.52	1.13	.060	.41	1.33	33600
16			.40	1.33	.050	.70	.75	32800
16	3.22	2.90	.32	1.34	.140	1.09	1.38	33360
16	2.90	2.60	.30	1.63	.120	1.10	1.29	30400
16	3.09	2.31	.78	1.31	.080	.29	1.51	36920
11	3.09	2.29	.90	1.31	.101	.91	.33	36600
37	3.23	2.68	.55	1.96	low	low	low	33376
37	3.25	2.75	.50	2.19	low	low	low	34944
67	3.20	2.50	.70	1.25	.070	.70	1.00	high
69	3.00	2.28	.72	1.31	.056	.66	.43	35430
70				1.66	.065	.70	.90	36000
70				1.60	.063	.72	.85	37300
70				1.70	.070	.70	.75	30400
70				1.70	.075	.60	.92	31300
171	3.07	2.44	.63	.94	.050	.44	.31	31350
171	2.50	1.40	1.10	1.00	.050	.30	.60	33000
171	3.52	3.10	.42	1.53	.050	.29	.45	30000
171	1.71	.96	.75	.98	.060	.43	.43	34700
171	3.18	2.05	1.13	1.19	.055	.41	.42	37100
171	3.00	1.62	1.38	.71	.058	.54	.39	30100

For iron which is required to have the greatest possible resistance to shock, the points to be especially observed are as follows:

Keep the phosphorus as low as practicable, still having the necessary fluidity. It should best be below .30%.

Keep the sulphur as low as possible.

If practicable add vanadium or titanium to the ladle, either in the form of ferro alloy or as thermite.

Table V gives the analyses of a large number of strong irons collected from many different sources. Attention is particularly called to the fact that the total carbons average quite low and the manganese is, with very few exceptions, quite high.

ELASTIC PROPERTIES

Of the elastic properties of metals, only toughness and its opposite, brittleness, and elasticity and its opposite, rigidity, are ordinarily considered in cast iron.

Toughness is defined as resistance to breaking after the elastic limit is passed (102, p. 486).

Elasticity is the amount of yield under any stress up to the elastic limit.

It is unusual for these properties to be determined separately in cast iron, but their sum is given by the deflection which is determined in transverse testing. It is probably true that they nearly always vary together and, hence, that deflection is a fairly good measure of either one as well as both.

Toughness is practically always a desirable quality in cast iron, but the same is not true of elasticity since in many machines great rigidity is a prime requisite.

The factors influencing toughness and elasticity are about the same as those influencing strength, *i.e.*, the chemical composition, presence of oxide and size of graphite. All these factors are of importance, so much so that it is hard to give them any order. In general, to get a tough, elastic iron we

should keep sulphur, phosphorus and combined carbon low; manganese, no higher than is necessary to take care of the sulphur; graphite and silicon, the less the better, *providing* that the combined carbon is not increased; and finally, use metal of good quality, melted carefully so as to be free from oxide.

In ordinary gray iron castings it is not practicable to attempt to control the graphite, since the combined carbon needs first attention and the graphite will necessarily be the difference between total carbon and combined carbon. The silicon also must be adjusted with a view to regulating the combined carbon. Practical rules for getting the maximum toughness and elasticity will then be about as follows:

Silicon—1.5% to 2.0% for castings of average thickness, more or less for very light and very heavy castings respectively.

Sulphur as low as practicable, best under .080%.

Phosphorus as low as practicable considering the necessity for fluidity. Best under .50%.

Manganese from three to five times the sulphur.

Use good irons and good cupola practice to insure freedom from dissolved oxide. (See under "Strength," p. 92).

In case steel scrap can be used, *i. e.*, semi-steel made, the toughness may be considerably increased through decrease in the amount of the graphite and in the size of the grain. The other elements may remain about as before except that it may be necessary to run the manganese a little higher to counteract the greater tendency of the semi-steel to become oxidized.

As previously noted, rigidity is desirable in some cases. This is the converse of elasticity and may be obtained by the direct opposite of the rules given for obtaining elasticity. However, to get rigidity with the least sacrifice of strength and toughness it is desirable to use manganese and combined carbon rather than to increase phosphorus and sulphur. That is, we would lower silicon as much as necessity for softness will allow, and raise manganese to about 1% (or less in

very light work). It should be noted that manganese is particularly efficient in increasing rigidity since it accomplishes this end with comparatively little sacrifice of strength and toughness.

A few examples of very tough and elastic iron are as follows:

No.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Graph. Carb.	Total Carb.
1	2.50 to 2.75	.050	.30				
2	.80				.87	2.34	3.21
3	2.45	.092	.63	.43			
4	1.18	.084	.27	.30			
5	2.36	.064	.33	.24	1.08	2.15	3.23

No. 1 represents iron which in thin sections can be punched and bent (171, p. 217). No. 2 is an analysis of a gray cast iron which is exceedingly malleable (154). Nos. 3, 4, and 5 are gray irons showing deflections for the transverse test-bars rather higher than usual.

HARDNESS

Under the head of "Hardness" I have included both hardness proper and chilling properties. It will be necessary to consider these separately.

It is generally stated that hardness in cast iron is due chiefly to the presence of combined carbon and is only indirectly or to a less extent caused by other elements. The writer believes that this is not altogether true and that there is another factor causing hardness which has not heretofore been generally considered in the case of cast iron.

It is well known that when steel is hardened by quenching from a temperature above its critical point its carbon is not in the combined state but rather in a form known as hardening or solution carbon, while the iron is retained in the *gamma* allotropic form (see Part I, p. 37). It is the belief of the present writer that the same is true of cast iron and

that many cases of hardness are to be explained in this way. For example, Keep (172, p. 56) describes a sample of cast iron which was too hard to drill and yet contained only .60% combined carbon, and many analyses are on record of irons which have been quenched from comparatively low temperatures and are almost glass hard in spite of the fact that the combined carbons are under 1%. I think it probable that the hardness of high manganese irons is due chiefly to this same cause since manganese is known to favor the retention of *gamma* iron (see Part I, p. 66).

Granting for the present the truth of this theory, the presence of the *gamma* or hard form of iron is controlled by the rate of cooling and the percentages of metalloids present; so that for all practical purposes we can say that there are six factors which influence hardness, *i. e.*, the rate and manner of cooling; the combined carbon; silicon; sulphur manganese; and phosphorus. The first two of these are of the greatest importance and we will take up in reverse order, leaving the most important till the last.

Phosphorus has a slight hardening effect in large quantities but in amounts less than 1% its effects are nearly imperceptible and it does not become important until the amount exceeds commercial limits, or say, 1.5%. We may, therefore, usually neglect the effects of phosphorus in considering hardness.

Manganese, although usually regarded as a hardening agent, may sometimes soften iron. This anomalous result is explained by the action of manganese on sulphur. If the iron is high in sulphur and low in manganese the first additions of manganese will unite with the sulphur forming the comparatively inert manganese sulphide and thus softening the iron. If, however, the manganese be increased beyond the amount necessary to care for the sulphur increased hardness will result.

The hardness produced by manganese is of a rather peculiar character in that it does not always show in the ap-

pearance of the iron. For example, a pig iron containing 3% manganese may have a beautiful open gray fracture and yet be so hard as to be drilled only with great difficulty. In addition, the presence of manganese sometimes produces a peculiar kind of gritty hardness, the iron acting as if containing small, hard grains. With regard to the amount of manganese required to produce hardness it will be evident that this depends largely on the per cent of sulphur present and also on the rate of cooling. In general, heavy castings will stand up to 1% of manganese without noticeable increase of hardness, medium castings about .75% and light castings .50%.

Sulphur is an exceedingly energetic hardening agent acting, however, chiefly through the carbon. That is, sulphur has a strong tendency to keep the carbon in combined form and in that way to harden. As noted in Part I, page 50, each .01% sulphur will increase the combined carbon by about .045%, other things being equal. It must be remembered, however, that this applies only to sulphur in the form of iron sulphide, and that in the form of manganese sulphide, *i. e.*, in the presence of about three times its weight of manganese, it acts much less energetically.

Sulphur also has a direct action in hardening, iron sulphide and manganese sulphide being quite hard substances. Usually this action is imperceptible, but occasionally one meets with hard spots which are due to the segregation of these sulphides.

Silicon is generally known as a softening agent and, within reasonable limits, has this effect due to its action in decreasing the combined carbon. The direct effect of silicon, however, is to harden since it forms with iron a compound which is harder than the iron itself.

When silicon is added to cast iron its first effect, as before stated, is to decrease the combined carbon. This, it does, at the rate of about .45% for each per cent of silicon added. (See Part I.) Actually the rate of decrease is more rapid than this and, in consequence, by the time we have

from 2 to 3% silicon present (depending on the rate of cooling) we have practically all the combined carbon precipitated out as graphite and hence, there is no further possibility of softening in this way. Now, any increase in silicon only increases the amount of the hard iron-silicon alloy, there is no more combined carbon to be decreased, and hence, the hardness will now be increased again. In other words, it is possible to have too much of a good thing, the good thing in this case being silicon.

The actual percentage of silicon which is necessary to secure any given degree of softness will depend upon the size of the casting, the nature of the mold, and the amount of sulphur and manganese present. It is therefore impossible to give definite silicon standards unless each of these factors is known. Fig. IX, which is taken from Turner (131, p. 195), shows the approximate relationship between silicon and hardness for castings of medium thickness.

Combined carbon (or solution carbon) is the chief hardening agent of cast iron, and, under ordinary conditions, the hardness of the metal will be closely proportional to the percentage present. Of such relative unimportance are the effects of the other elements that it has been found practicable to use the amount of combined carbon as a measure of the hardness of castings and as a means of predicting their behavior in the machine shop (96, 103). It is recommended that foundries having their own laboratories pay more attention to this question of combined carbon and regulate the hardness of their castings by it directly. This can be done very accurately in the foundry since the variations in practice will rarely be great enough to allow of the direct action of the metalloids to have an appreciable effect; and the only other hardening agent is varied in the same direction and by the same factors as the combined carbon.

To machine easily, cast iron should not contain over .75% combined carbon. 1.00% combined carbon gives a pretty hard casting, and 1.50% is about the upper limit for iron to be machined.

The rate and manner of the cooling of the casting are

usually supposed to influence its hardness only as it affects the percentage of combined carbon. That it does affect the

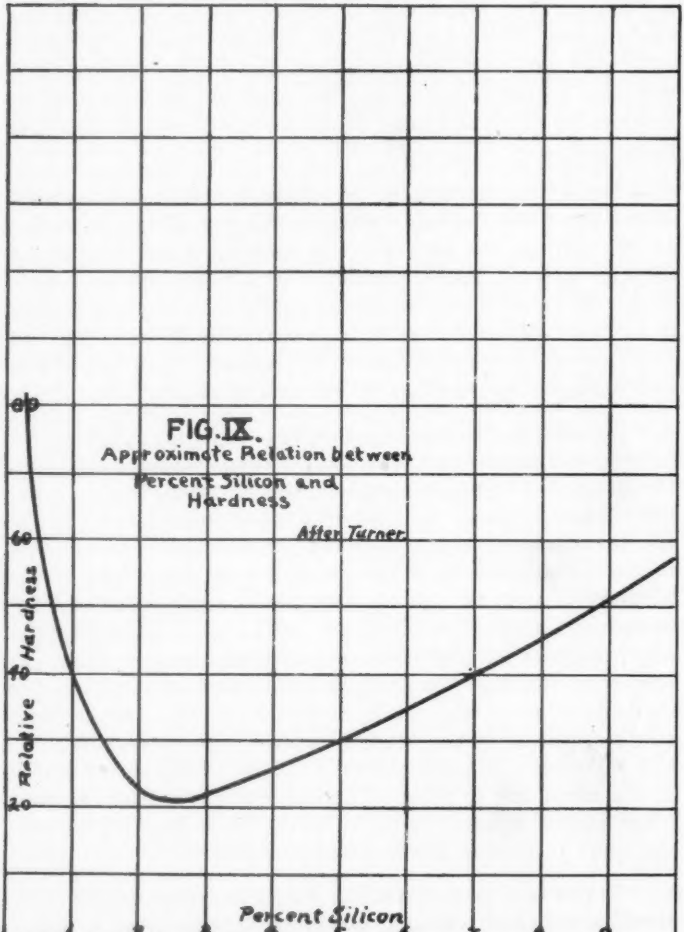


FIG. IX.
Approximate Relation between Percent Silicon and Hardness

amount of combined carbon is a well established fact and in Part I, page 47 is discussed their quantitative relationship.

As explained in a preceding paragraph, however, we sometimes get hardness in the absence of any considerable amount of combined carbon. Hence, there must be some other factor at work, which, in the writer's opinion, is a solution of carbon in *gamma* iron, the hard constituent of tool steel.

According to this theory, combined carbon disappears in the temperature range 2200° to 1500° F., while *gamma* or hard iron is not transformed into the *alpha*, or soft variety, until the casting has cooled to about 1300°. Evidently, then, ordinary rapid cooling of castings from the molten state results in both high combined carbon and high *gamma* iron, and hence we have hardness due to both of these causes. The more rapid the cooling, the higher the combined carbon and the higher also the *gamma* iron, therefore, since both vary together, the percentage of combined carbon is a satisfactory measure of the hardness produced by both factors.

If now, the conditions of cooling are changed this need no longer be the case. For example, suppose we cool the casting slowly from the molten state down to 1600° and then quench it in water. In this case we would get nearly all combined carbon changed to graphite during the slow cooling through the upper range, while the rapid cooling through 1300° preserves the *gamma* iron solution and hence gives hardness due to this cause.

Some of the peculiar things noted in connection with Custer's process of casting in permanent molds are to be explained on this basis. Also, the much greater softness of castings which have been allowed to cool in sand, and thereby anneal themselves over those shaken out soon after being poured.

Chilled iron is simply white iron, that is, iron in which graphite is absent and the carbon all in the combined or solution state. The same iron may be both gray and white depending on rate of cooling and hence, the exterior of the casting, if rapidly cooled, may be white while the interior which cools more slowly remains gray. Usually there is an intermediate zone having a mottled structure formed through the

interlacing and the gradual merging of the gray and white. A chilling iron, then, is one which when rapidly cooled contains all of its carbon in the combined state. The factors which influence the depth and quality of chill are the temperature at which the iron is poured, and the amounts of silicon, sulphur and phosphorus, manganese and total carbon, besides some of the elements which are not normally present in cast iron, but which are occasionally added.

The higher the temperature at which iron is poured the deeper the chill, other things being equal, and it is usually considered advisable to pour chilled castings from hot iron. The quantitative effects of pouring temperature have been studied by Adamson (58) and, while there are some conflicting results, it is in general indicated that in the case of the strongly chilling irons an increase of 50° in the pouring temperature causes an increase of from $\frac{1}{8}$ to $\frac{1}{4}$ inch in the depth of the chill.

The most important element in its effects on chill is silicon since it is this which has the strongest action in precipitating graphite. For chilling iron silicon should be low, but how low depends on the thickness of the casting, the temperature of pouring and the depth of chill desired as well as on the percentage of other elements in the iron. Table VI gives a very approximate relationship between the percentage of silicon and depth of chill, other elements being about normal.

TABLE VI

APPROXIMATE RELATION BETWEEN PER CENT. SILICON AND DEPTH OF CHILL

% Silicon	Depth of Chill
1.50%	$\frac{1}{16}$ inch
1.25	$\frac{1}{8}$ "
1.00	$\frac{3}{16}$ "
0.75	$\frac{3}{8}$ "
0.50	$\frac{3}{4}$ "
0.40	1 "

Sulphur tends to increase the combined carbon, and, hence, the chill. So marked is its influence in this respect that it is sometimes added to cast iron to increase the depth of the chill. This, however, is not usually good practice since the chill imparted by sulphur is lacking in toughness

and strength as well as in resistance to heat strains (14, 171). Scott cites the case of stamp shoes for mining machinery where sulphur was used to increase the chill. The shoes were very hard at first, but soon went to pieces under the repeated blows (14). Johnson, also (34), has noted the great difference between high and low sulphur chilled iron as regards ability to withstand the strains of sudden cooling without cracking. On the other hand, West states (171) that the chill produced by sulphur is very persistent to frictional wear, and, hence, it may be inferred that sulphur adds to the life of castings which are subject to abrasion. It has been stated that the presence of a small amount of sulphur is essential in order to get the best results in chilled rolls. This, however, is doubtful and it is believed that it is only rarely that sulphur is desirable in chilled castings. The presence of a moderate amount of manganese in cast iron greatly lessens the bad effects of sulphur in chilled as well as in gray iron castings.

Phosphorus in the amounts ordinarily present in the commercial cast iron has but slight influence on the depth of the chill but does have a more or less injurious effect on its strength. It is generally stated that high phosphorus has the effect of causing a sharp line of demarkation between the gray and chilled portions of the casting (63, 171 p. 261). The evidence, however, is conflicting for Adamson (58) states just the contrary, viz., that phosphorus makes the interlacing of gray and white very pronounced. It is believed that it is best to limit the phosphorus in chilled iron to about .4%.

Manganese, since it tends to increase the combined carbon also tends to increase the chill. However, it must be remembered that the first effect of manganese is to neutralize sulphur, and, therefore, in small amounts it may indirectly decrease the chill. See also page 61. Manganese very greatly increases the hardness of the chill, and, to a less extent, its strength. It also increases the resistance of the chill to heat strain and hence diminishes the danger of surface cracks in such castings as chill rolls and car wheels. Still another effect is the promotion of a more gradual merging of the gray and chilled portions of the castings. (171, p. 261).

Manganese is usually considered a desirable constituent of chilled iron and the amounts used vary all the way from .40 up to 3.0%. It is probable that a part of its good effects are due to its deoxidizing action.

Of late years semi-steel mixtures have been used to some extent for chilled castings, the total carbon being considerably lower than in the ordinary mixture. The effect of low total carbon is to give a deep and comparatively soft chill as compared with the shallow, hard chill obtained with high total carbon.

It has been proposed to use nickel as a means of controlling chill (101), this element having an effect somewhat similar to silicon. Hence, by starting with a strongly chilling iron and adding nickel the depth of the chill would be lessened in some ratio to the amount of nickel added. Since the same results may be obtained by the use of less expensive silicon it is difficult to see any advantage in adding nickel.

The quality of chilled iron may be very greatly improved by the addition of small amounts of titanium or vanadium. The beneficial effects of these elements are probably due chiefly to their deoxidizing power. For further particulars as to their action see pages 75 to 80. Of the other deoxidizing agents manganese has already been spoken of and silicon and aluminum are out of the question because of their power of causing the formation of graphite.

GRAIN STRUCTURE

The fracture or grain size and the porosity are closely related and are both dependent primarily on the size of the graphite particles and, to a less extent, on the percentage of graphite. The factors influencing the amount and size of the graphite have been thoroughly discussed under the head of "Strength," pages 82 to 92, hence it only remains to summarize the points to be observed in making mixtures for close, dense iron such as is desired for cylinders and hydraulic work.

Silicon should be kept just as low as possible and still have the castings soft enough to machine. The exact percentage will depend on the thickness of the casting, the character of the mold and whether the casting is allowed to anneal itself or is quickly shaken out after pouring. It may range from .75% for very heavy work up to 2.0% for small valves, etc. It is believed that the majority of founders use more silicon than is best in work of this character.

Combined carbon has a powerful action in closing the grain and giving a dense iron and should be just as high as possible and still have the iron machinable. Diller (103) found that with radiator loops combined carbon over .70% brought a complaint of hardness from the machine shop while if under .40% they would usually fail under the hydraulic test.

Manganese had best be kept moderately high since it appears to have some beneficial effect in closing the grain.

Sulphur is a powerful agent in closing the grain and is frequently made purposely high for this end. It is, however, a dangerous agent since it may cause trouble in other directions, and as a general proposition it is better to keep the sulphur low and get necessary density by a proper regulation of silicon and manganese.

Finally, one of the best, if not the best, means of closing the grain of cast iron and securing the maximum density is by means of steel scrap in the mixture. This is now common practice with makers of hydraulic castings and is very effective. The precautions necessary in making semi-steel mixtures have been discussed on pages 84 to 86.

SHRINKAGE

In considering the shrinkage of cast iron it is necessary to distinguish between the contraction of the fluid mass previous to and during the act of solidifying and the contraction

of the solid mass. The first is that form of shrinkage which necessitates feeding in heavy castings, and which so often results in shrink holes or spongy places in heavy sections of castings which are not fed. West (171, p. 386), calls this contraction of the fluid mass "shrinkage."

The contraction of the solid mass represents more nearly what is generally called shrinkage, this term as ordinarily used meaning the difference in size between the casting and its pattern. This contraction of the solid mass West (171, p. 386) calls "contraction."

The mechanism of fluid contraction is not well understood but probably Professor Howe's theory (180, p. 17 to 31) of a "virtual expansion" of the outer walls of the freezing casting is very near the truth. I can hardly attempt here to repeat his explanation since the conceptions are very difficult and would necessarily involve a very lengthy discussion. Whatever the explanation may be, however, it is in general true that the greater the amount of graphite formed the less is this contraction, hence, the well known fact that the harder grades of iron require the most feeding. The factors upon which the amount of graphite depends have been discussed on pages 83 to 87.

It seems necessary to make some distinction between the total amount of fluid contraction and the tendency to form shrink holes in the heavy sections of small castings. At least there seems to be no very definite relation between chemical composition and this latter property and it is often the case that an iron low in graphite, and therefore having a high fluid contraction, will give sounder castings than another iron high in graphite and which would, therefore, require less feeding in a large casting. In the writer's opinion, this difference is probably due to some peculiarity in the *manner* of freezing, but the whole subject is as yet enveloped in obscurity.

Cook (69) has found that two irons of practically identical chemical composition may give very different results

as regards soundness when poured into small castings of heavy section and the writer can confirm this fact from his own experience. A convenient test has been developed by Cook to show the tendency of any particular brand of iron to trouble of this sort. This test consists in making a casting in the shape of a K, the branches having a cross section of one inch square. On breaking off the oblique branches any tendency to sponginess or shrink holes will at once be evident in the fracture.

As before stated there has thus far been discovered no important relationship between this property and chemical composition. It rather appears to be something inherent in the brand of iron. The writer has been told that in one case an addition of phosphorus lessened the difficulty and it is a curious fact that in some instances at least the addition of a small amount of steel scrap to the mixture will act as a partial corrective.

The contraction of the solid mass does not take place uniformly as the casting cools but in stages which are separated by periods of less contraction or even of actual expansion. The total shrinkage which perhaps includes also a portion of the shrinkage in the fluid mass is conveniently obtained by Keep's test (172, p. 182) or by casting a test bar between iron yokes and determining the space between the end of the bar and the yoke after cooling.

This, however, tells nothing as to the manner of shrinkage or the temperature at which it takes place. To get this latter information we must determine the shrinkage curve, or in other words, the length of the test bar at each instant of time during cooling, starting from the instant when the bar has solidified just enough to have some slight strength. West (171, p. 397), Keep (172, p. 50), and Turner (36) have described forms of apparatus for making these curves. Fig. X shows some typical shrinkage curves and illustrates the relationship between chemical composition and the form of these curves.

It will be noted that there are three periods of expansion separated by intervals during which the shrinkage takes

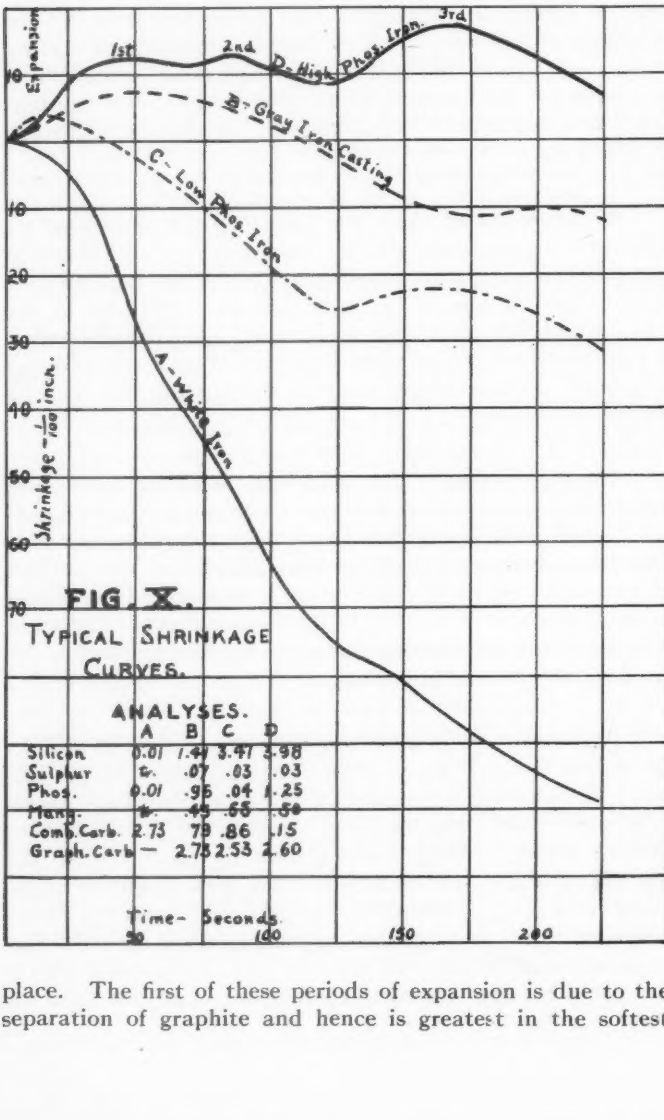


FIG. X.
TYPICAL SHRINKAGE CURVES.

ANALYSES.

	A	B	C	D
Silicon	0.01	1.41	3.47	3.98
Sulphur	tr.	.07	.03	.03
Phos.	0.01	.95	.04	1.25
Mang.	tr.	.45	.65	.50
Comb. Carb.	2.73	79	.86	.15
Graph. Carb	—	2.75	2.53	2.60

place. The first of these periods of expansion is due to the separation of graphite and hence is greatest in the softest

irons. Note that in the case *A* which is a white iron and contains no graphite this expansion is entirely lacking. This expansion takes place within the temperature range 2200° to 1800° F. or immediately after the iron has solidified.

The second expansion is due to the solidification of the phosphide eutectic with a consequent secondary precipitation of graphite at that time. Evidently, this expansion is only to be expected in high phosphorus irons and it will be noted that it is lacking in *C* which is low in phosphorus and is well marked in *D* which is high in phosphorus. This expansion takes place within the temperature range 1800° to 1500°F.

The third expansion is, in the writer's opinion, due to the change of the iron from the *alpha* to the *gamma* form, since it takes place within the temperature range 1400° to 1200° F. or about where this change would be expected to take place. Note that this expansion is greatest in high silicon irons *C* and *D*, silicon having the effect of accelerating the *gamma* to *alpha* change. The point at which this third expansion occurs probably marks the lower limit below which iron cannot be hardened by quenching.

The study of these curves is very interesting to the experimenter and it is believed that when we understand them better they may become of practical value to the foundryman. At present, however, the determination of total shrinkage gives information which is of more immediate value.

The effect of composition on total shrinkage is given in concise form by the following tabular statement:

Silicon	Decreases by about	.01 "	per ft. for each	.20%	(14)
Sulphur	Increases " "	.01 "	" " " "	.03%	(14)
Phosphorus	Decreases " "	.015"	" " " "	.10%	(14)
Manganese	Increases " "	.01 "	" " " "	.20%	
Total Carbon	Decreases				

To get the minimum shrinkage an iron should be high

in silicon, from 2 to 3% depending on the thickness, high in phosphorus, say, .75 to 1.25%, as low as possible in sulphur, as high as possible in total carbon and with only enough manganese to care for the sulphur, or say, .3 to .4%. This will insure high graphite and hence low shrinkage in the casting. The iron will, however, be rather weak and it is something of a problem to get in one and the same iron considerable strength and at the same time very low shrinkage.

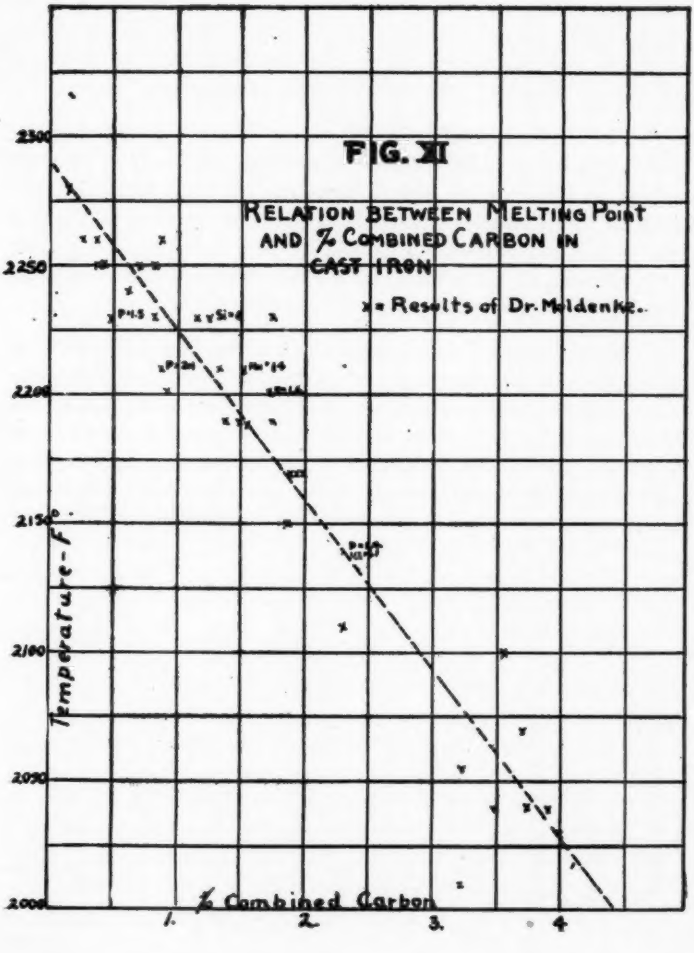
By the term "stretch" West (171) describes the power of cast iron to stretch when placed under strain during the cooling process. This property is undoubtedly of much importance in cast iron since there are many castings which are called upon to exhibit it. An extreme case which is commonly cited is that of pulleys, the arms of which are placed in tension due to the quicker cooling of the rim and which must, therefore, either stretch or crack. There is no data regarding the effect of the various metalloids of cast iron on its power of stretching but in general a soft iron will stretch more than a hard one. Almost the only data on this subject is given by West (171, p. 418). He finds that the period of greatest stretching of cast iron is within the temperature range 1600° to 1200° F. He describes an apparatus by means of which the amount of stretch can be determined and records a case in which by stretching the length of a 3-foot, 4 inch bar was increased more than ¼ inch as compared with a similar bar which was not stretched during cooling.

FUSIBILITY

Fusibility or the melting point of cast iron, must not be confounded with its fluidity, or ease of flow when molten. Fluidity is much the more important of these two properties, but fusibility is of some interest, particularly as it gives us a means of deciding intelligently in what order to charge metals in the cupola.

The investigations of Dr. Moldenke (62) have shown that

the fusibility of cast iron depends primarily on its combined carbon content and, to a less extent, on the amount of phos-



phorus present. From the iron-carbon diagram, Fig. I, we see that the most fusible alloy of iron and carbon, contain-

ing 4.27% carbon, should have a melting point of 2195° F. and as the carbon decreases the melting point increases up to 2730° F. for pure iron. Actually, we find that cast iron has a melting range varying from 2000° F. for a white iron up to 2300° F. for gray iron containing practically no combined carbon, this difference being due probably to the presence of silicon, sulphur, phosphorus, and manganese.

Since the graphite in gray iron is only in mechanical mixture with the iron we should, perhaps, expect it to have no effect on the melting point. Moreover, it combines with the iron at temperatures below the melting point thus increasing the combined carbon and lowering the melting point. For this reason gray iron melts at a lower temperature than steel having the same percentage of combined carbon.

As previously noted, phosphorus also has the effect of lowering the melting point of cast iron but it is not nearly as powerful in its action as combined carbon. Iron containing 6.7% phosphorus would melt at only 1740° F. but with less phosphorus than this the melting point rises rapidly so that the 1 or 2% present in commercial high phosphorus irons makes very little difference in the melting point.

TABLE VII

MELTING POINTS OF CAST IRONS

Melt. Pt.	Com.Carb.	Graph.	Sil.	Mang.	Phos.	Sul.	
2030°F.	3.98%		.14%	.10%	.22%	.037%	pig iron
2100	3.52	.54	.47	.20	.20	.036	" "
2140	2.27	1.80	.45	1.10	1.46	.032	" "
2170	1.93	1.69	.52	.16	.76	.036	" "
2200	1.69	2.40	1.81	.49	1.60	.060	" "
2210	1.48	2.30	1.41	1.39	.17	.033	" "
2230	1.12	2.66	1.13	.24	.089	.027	" "
2210	.84	3.07	2.58	.47	2.12	.051	" "
2250	.80	3.16	1.29	.50	.22	.020	" "
2280	.13	3.43	2.40	.90	.08	.032	" "
2350	1.32		.21	.49	?	?	steel
2210	6.48	(carbon)	.14	44.59	?	?	ferro mang.
2255	5.02	(carbon)	1.65	81.40	?	?	ferro mang.
2190	3.38	.37	12.30	16.98	?	?	silico spiegel
2040	1.82	.47	12.01	1.38	?	?	ferro silicon
2400	6.80	(carbon)	(chromium 62.70)				ferro chrome
2280			(tungsten 39.02)				ferro tungsten

Fig. XI gives in graphic form the data of Dr. Moldenke (62) from which is drawn a line representing the approximate melting point of cast iron of any per cent combined carbon.

Table VII gives the melting points with analyses of some typical irons and ferro alloys selected from the above data. It will be noted that the metalloids other than carbon and phosphorus, *i.e.*, the silicon, sulphur and manganese, seem to have very little effect on the melting point.

FLUIDITY

Fluidity may be defined as ease of flow. It is synonymous with mobility and opposed to viscosity. It is a property of far reaching importance to the foundryman and especially to the manufacturer of small and intricate castings. Unfortunately, our means of measuring fluidity are not very satisfactory, and this makes it difficult to determine quantitatively the effect of composition upon this property. About the most satisfactory method is to pour fluidity strips (171, p. 374), or long strips of perhaps one square inch section and tapering to nothing at the other. The distance which the iron runs in a mold of this form is a rough measure of its fluidity.

The factors which govern fluidity are percentage of silicon, percentage of phosphorus, freedom from dissolved oxide, and temperature above the melting point.

Silicon perhaps aids fluidity by causing a separation of graphite at the moment of solidification, thus according to Field (181) liberating latent heat and prolonging the life of the metal. On this basis, high total carbon would also aid fluidity by increasing the amount of graphite separated.

Phosphorus is probably the most important element as regards fluidity, high phosphorus causing a marked increase in this property. The best results are obtained with about

1.5% phosphorus, although for other reasons it is seldom desirable to use as much as that.

Freedom from oxide is a very important point as its presence makes the metal sluggish and causes it to set quickly. It is a frequent and often unsuspected source of trouble. Dissolved oxide may be eliminated by any of the methods described on pages 70 and 71.

The temperature above the freezing point is probably the most important factor of all in connection with fluidity, and it should here be noted that a distinction is made between freezing point and melting point. The two may coincide in the case of white iron, but will not usually especially with gray iron. This is because, as we have already seen, gray irons have a melting temperature corresponding to their percentage of combined carbon rather than total carbon. After they are in the molten state, however, all the carbon is in solution (combined as far as melting points are concerned), hence the freezing point will correspond more nearly to the melting point of a white iron having the percentage of combined carbon equal to the total carbon of the original gray iron. This will be in general from 100° to 300° lower than its melting point. For this reason when gray irons are melted they are always considerably superheated above their solidifying points, and the greater this superheat, the more fluid the iron. Evidently, the superheat due to this cause will be the greater the lower the combined carbon in the iron going into the cupola.

Practical rules for getting fluid iron are as follows:

Keep the phosphorus high. Up to 1.00 to 1.25% if possible.

If the work will permit use a soft iron of 2% or over silicon and low in combined carbon.

Avoid oxidizing conditions in melting, and if necessary, use deoxodizing agents.

Use plenty of coke and good cupola practice.

RESISTANCE TO HEAT

Ability to withstand high temperatures is of paramount importance in several classes of castings such as grate bars, ingot molds, annealing boxes, etc. and the factors which affect this ability are, the percentage of phosphorus, sulphur, and combined carbon, and the density or closeness of grain.

As explained more fully in Part I (page 59) phosphorus forms with iron an alloy which melts at only 1740° F. or about 400° lower than cast iron free from phosphorus, and each per cent of phosphorus present gives rise to 15% of this easily fusible constituent. Now, it will be evident that the presence of a molten constituent in a piece of iron must greatly weaken it, and hence it is that the presence of much phosphorus decreases the resistance of cast iron to heat.

Sulphur acts in a similar manner to phosphorus since it also forms with iron a constituent of low melting point (1780° F.). It is, therefore, detrimental to castings which have to stand high temperatures.

As previously noted (p. 114) combined carbon is the element which more than any other determines the melting point of cast iron, this melting point becoming lower with increase in this element. It would seem then, that combined carbon must be very detrimental in this class of castings. However, it should be remembered that the condition of the carbon in the solid iron changes readily at high temperatures, and, hence, after the casting has been in use for a while its combined carbon content will not in general be the same as when cast. This fact makes the question of combined carbon of much less practical importance than either phosphorus or sulphur.

Density or close grain is commonly stated to render cast iron considerably more resistant to the effects of heat. The means of securing close grain are discussed on pages 86 to 91.

One feature of the effect of heat on cast iron which deserves especial mention is the permanent expansion which it undergoes on repeated heatings. This peculiar behavior was first discovered by Outerbridge (125, 30), and has since been also investigated by Rugan and Carpenter (183).

The extent to which this growth may take place is certainly surprising, the increase being in some cases as high as 46% by volume and 1¾ inches in the length of a 15 inch bar. The strength of the metal is decreased proportionately to the expansion or to about one-half of the original strength. Both the expansion and the decrease in strength are explained by microscopic examination which shows minute cracks throughout the interior of the metal. Outerbridge found that in his experiments the increase in hardness was accompanied by no increase in weight and that the specific gravity of the metal was decreased from the original 7.13 to 5.49. Rugan and Carpenter, on the other hand, found invariably an increase in the weight of the expanded bars due to the absorption of oxygen by the metal.

Two conditions are necessary for this growth. First, repeated heatings, and second, a proper composition of the metal.

With regard to the heating, a minimum temperature of 1200° F. is necessary. At 1400 to 1600° the rate of growth is more rapid and an increase in temperature beyond 1700° produces no additional effect. Both heating and cooling are necessary to procure the growth and the time of heating makes very little difference. No greater growth was produced by 17 hours continuous heating than by 4 hours. The number of heatings required to produce the maximum amount of growth varies with different irons, but usually lies somewhere between 50 and 100.

Regarding the effects of composition, it appears that the growth is favored by the presence of graphite and silicon, and also by a large grain or open structure. White iron containing no graphite expands slightly when subjected to this

treatment but not sufficiently to overcome its original shrinkage. In this case the expansion is due to the conversion of the combined carbon into the temper form, or in other words, to the malleableizing of the casting. Soft irons low in combined carbon and high in silicon show the greatest increase in volume. The effects of sulphur, manganese and phosphorus have not been investigated. Steel and wrought iron are not subject to this growth, but on the contrary undergo a slight permanent contraction when repeatedly heated.

Authorities differ as to the explanation of this phenomenon. Outerbridge attributes it to the "mobility of the molecules of cast iron," while Rugan and Carpenter conclude that it is due to the oxidation of the iron silicide by air admitted through minute cracks opened up along the faces of the graphite crystals, or in some cases, to pressure exerted by the expansion of the occluded gases. To the writer it seems that this growth must be due to the fact that iron undergoes a change in volume coincident with the change from the *alpha* to the *gamma* form when heated to its critical temperature of about 1300° F., and that the mechanical interference of the graphite crystals prevents the return of the iron crystals to their original positions in the subsequent cooling. This explanation is, perhaps, only an amplification of that of Mr. Outerbridge.

It is evident that this property of cast iron is of great importance in many of the applications of the metal and limits its use for many purposes. It is, no doubt, the reason why a close-grained iron gives better results when exposed to high temperatures and affords an explanation for the warping of grate bars, annealing boxes and similiar castings. It also shows why chills and permanent molds must not be allowed to be heated to redness, such a degree of heat resulting in permanent expansion and the loss of their original dimensions.

The following is a summary of some of the published statements regarding the proper composition for castings exposed to high temperatures:

Cast iron to withstand high temperatures should be low in phosphorus and combined carbon (14).

In car wheels manganese increases the resistance to heat strain (51).

For refractory castings choose a fine grain cast iron, best containing about 2% manganese to retard the separation of amorphous carbon (60).

Castings to resist heat should contain about 1.80% silicon, .03% sulphur, .70% phosphorus, .60% manganese, and 2.90% total carbon. Low sulphur is of chief importance, low silicon, carbon and manganese are also advisable (81).

Close-grained cast iron having the greatest density will invariably be found best to withstand chemical influences and high temperatures (85).

A chill which had given excellent service had the following composition: silicon, 2.07%; sulphur, .073%; phosphorus, .03%; manganese, .48%; combined carbon, .23%; graphite carbon, 2.41%; total carbon, 2.64% (105).

Two permanent molds which had given excellent service analyzed as follows:

	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Graph.	Tot. Carb.
(134)	2.15%	.086%	1.26%	.41%	.13%	3.17%	3.30%
	2.02	.070	.89	.29	.84	2.76	3.60

Ingot molds and stools are best made from medium soft iron low in phosphorus, or what is termed a regular Bessemer iron (171).

It will be noted that some of these statements are quite contradictory which simply means that it is not absolutely necessary for a casting to fulfil all of the requirements which we have previously discussed in order to give satisfactory

service. It is, however, probable that had all these conditions been fulfilled the service would have been even more satisfactory.

BEHAVIOR AT LOW TEMPERATURES

It is well known that steel becomes much more brittle at low temperatures and this fact is reflected in specifications for steel rails which are to be used in very cold climates. It is not known whether the strength and other properties of cast iron are materially affected by great cold. Even if so its influence cannot be great and the subject is of comparatively small importance. Dewar and Hadfield have carried out experiments on the properties of metals at the temperature of liquid air and find in the case of iron and steel an increase in strength and a decrease in ductility. The presence of manganese increases the brittleness due to cold while the presence of nickel and manganese together lessens this brittleness.

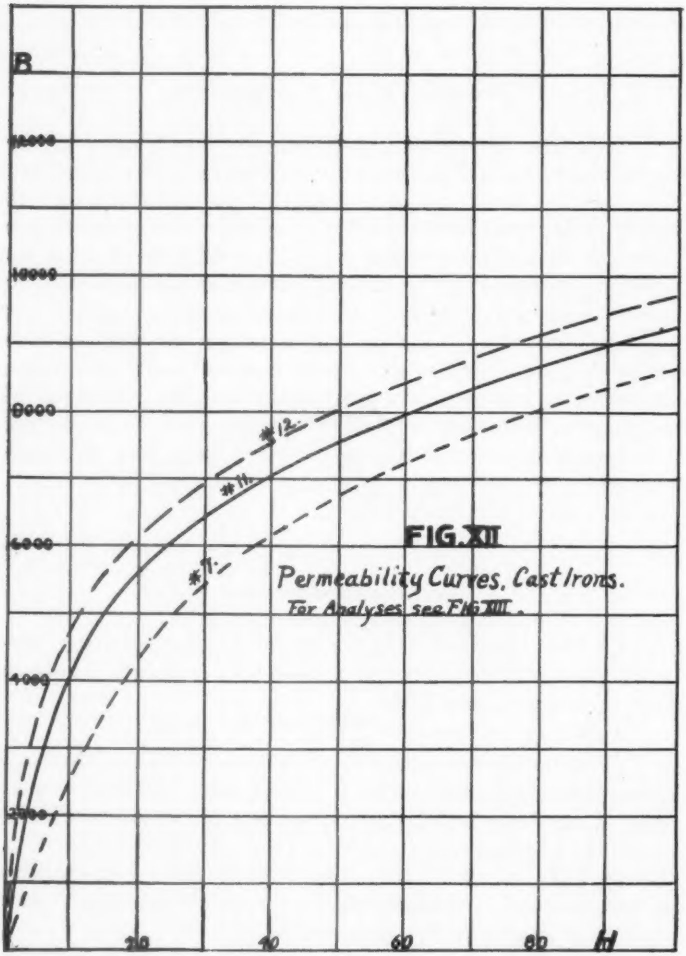
ELECTRICAL PROPERTIES

Of the three electrical properties, conductivity, permeability, and hysteresis, the second only is of importance in connection with cast iron.

Little is known regarding the relation between chemical composition and conductivity of cast iron. In the case of steel it has been found that manganese is the element most injurious to this property with carbon a close second (185). Hence, by analogy we may infer that to make iron castings of high conductivity we should keep both the manganese and combined carbon as low as possible.

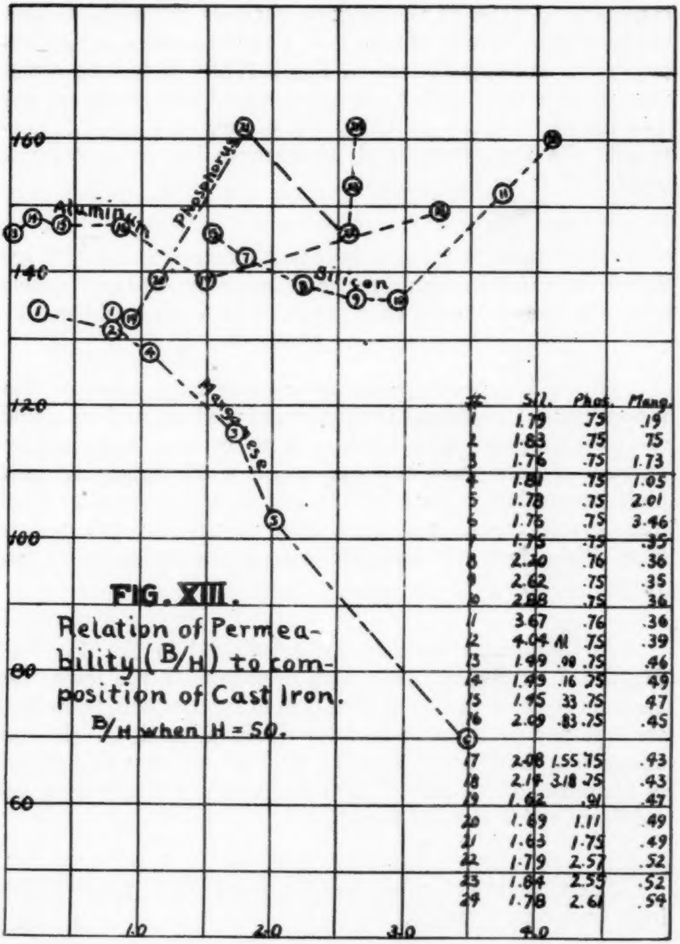
Permeability may be defined as magnetic conductivity and is of importance in many castings used in the construction

of electrical machinery. Permeability data is generally given in the form of a curve expressing the relation between



the magnetizing force H and the resulting field strength or number of lines of magnetic force per unit area B. This

is known as the permeability curve. The permeability is the ratio $\frac{B}{H}$ and it will be noted that it is different for each value



#	Sil.		Phos.	Mang.
1	1.79		.75	.19
2	1.83		.75	75
3	1.76		.75	1.73
4	1.81		.75	1.05
5	1.78		.75	2.01
6	1.76		.75	3.46
7	1.75		.75	.35
8	2.20		.76	.36
9	2.62		.75	.35
10	2.88		.75	36
11	3.67		.76	.36
12	4.04	Al	.75	.39
13	1.99	.08	.75	.46
14	1.49	.16	.75	49
15	1.95	33	.75	47
16	2.09	.83	.75	.45
17	2.08	1.55	.75	.43
18	2.17	3.18	.75	.43
19	1.62		.91	.47
20	1.69		1.11	.49
21	1.63		1.75	.49
22	1.79		2.57	.52
23	1.84		2.55	.52
24	1.78		2.61	.54

FIG. XIII.
Relation of Permeability (B/H) to composition of Cast Iron.
B/H when H = 50.

of the magnetizing force, H, but approaches a constant or saturation value for high values of H. See Fig. XII.

The effects of the various elements on permeability are not yet entirely clear although there is some published data along this line. (186, 187). The writer has recently done considerable work on the relation between permeability and chemical composition of cast iron, and the results, as yet unpublished, are summarized in Fig. XIII.* It will be noted that the effects of silicon, phosphorus and aluminum are not well marked and are probably not of any very great importance. On the other hand, manganese has a very detrimental effect on this property.

In the writer's opinion these bad effects of manganese are due to its action in retarding the change from *alpha* to *gamma* iron. It is well known that *gamma* iron is non-magnetic.

Silicon has the opposite effect from manganese in that it accelerates this change in the form of the iron, and we would therefore, expect it to have a more or less beneficial influence. Silicon steel has achieved a wide reputation as a high permeability material for use in the construction of transformer cores, etc. According to the author's results high silicon is particularly effective in increasing B for *low* values of H.

An important element not considered in the diagram, Fig. XIII, is carbon. For high permeability the lower the carbon the better, and excellent results are now being obtained through the use of semi-steel for electrical castings. In this connection, however, it must be remembered that manganese is undesirable and hence must be used cautiously as a deoxidizer in this class of work.

Some practical rules for obtaining high permeability iron are given herewith.

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* NOTE.—The writer is indebted to Prof. S. J. M. Allen of the University of Cincinnati, for the permeability tests on the samples of Fig. XIII.

Keep the silicon high, best in the neighborhood of 3%.

Keep the manganese low, preferably below .5%.

If practicable keep the carbon low by the use of steel scrap or air furnace iron.

Allow the castings to anneal themselves, *i. e.*, cool completely in the sand before shaking out.

Hysteresis, like conductivity, is seldom or never of importance in cast iron. The property may be defined as the loss of energy due to molecular friction when magnetic polarity is reversed. The effect of composition upon hysteresis is in general about the same as in the case of permeability.

RESISTANCE TO CORROSION

The relation of the composition of cast iron to its resistance to corrosion has apparently never been systematically studied and the little that is known on the subject is, for the most part, carefully guarded by the possessors of the information. Although there are a great many corrosive agencies it is not practicable, because of lack of information, to treat of each separately, and so far as we know the effects of composition would be relatively the same for the various corroding agents.

The following is a summary of most of the published information along this line:

Pig iron which best resists acids contains silicon 1.0%; phosphorus 0.5%; sulphur .05%; carbon 3.0% (7).

Excellent results with respect to resistance to corrosion by acids were obtained through the use of a mixture of three brands of pig iron *A*, *B*, and *CC* in the proportion, two parts of *A*, one part *B* and one part *C*. The analysis of the pig irons is thus given (42).

	Fracture	Silicon	Mang.	Phos.	Total Carb.
A	Dark gray	3.50%	0.50%	0.20%	3.80%
B	Light gray	1.50	0.40	0.20	3.50
C	Mottled	0.70	0.25	0.20	3.50

The composition of acid resistant castings should be about as follows:

Silicon	Sulphur	Phosphorus	Manganese	Total Carbon
0.8 to 2.0%	.02 to .03%	.40 to .60%	1.0 to 2.0%	3.0 to 3.5%

and, in addition, the metal should be as free as possible from oxide (81).

Cast iron to withstand the corrosive action of molten chemicals should be close grained and dense. The iron having the greatest density will invariably be found to best withstand chemical influences and high temperatures. The addition of deoxidizing agents is of great benefit (85).

Gray iron is attacked by acids about three times as fast as white iron. In cases where it is not practicable to use white iron castings it is sometimes possible to cast against chills in such a manner as to form a white iron surface to resist corrosion, and still leaving the body of the casting gray (66).

In a series of tests on the acid resisting properties of some well known English brands of iron, the No. 1 iron, presumably high in silicon, and the "hematite," low in phosphorus and probably high in silicon gave the best results (175).

Ferro silicons with high percentages of silicon, 20% and over, are remarkably resistant to the effects of acids and are being made into vessels for use in the chemical industries (138, 161).

Sulphur has been found to be a source of corrosion in steel in some instances, causing pitting at points where manganese sulphide has segregated (139).

It has been shown that the presence of small amounts of copper in steel and puddled iron diminish their tendency to rust (166, 167).

Some practical rules for obtaining castings resistant to corrosion are as follows:

Use white iron if practicable.

If not practicable to use white iron castings, chill those surfaces which are to be in contact with the corrosive substances.

If gray iron must be used get dense, close-grained castings through the use of steel scrap or otherwise. (See page 107.)

Avoid oxidized metal, use good cupola practice and good pig irons. If possible use deoxidizing agents. (See page 70.)

Keep the sulphur just as low as possible.

RESISTANCE TO WEAR

We must first make some distinction between two cases of wear typified by a grinding roll and a brake shoe. The first case may be dismissed by the simple statement that the greater the hardness the better the wear providing at the same time that the iron is sufficiently strong.

In the second case, however, it is necessary that the casting should not be so hard as to unduly wear the material with which it comes in contact. For example, the brake shoe must be softer than the tread of the car wheel. There is no theory to guide us in the matter and the rules given are the results of experience chiefly with brake shoes.

Too much silicon gives an open, soft iron which does not wear well. The best results are obtained with silicon about 1½% in castings of medium thickness.

Sulphur is claimed by many to be advantageous in

castings for frictional wear because it closes the grain and hardens somewhat (14). Diller (96) records a peculiar occurrence of a hard spot which could not be machined, a smooth surface being formed which wore the drill although it could be dented with a center punch. Analysis showed .20% sulphur and .50% combined carbon.

Phosphorus is best kept moderately low. Most specifications call for .75% or under. It is injurious probably because it weakens the iron at the high temperature sometimes produced by friction.

Manganese is best kept moderately high to take care of the sulphur. Most brake shoe specifications call for under .70%.

The addition of steel scrap to the mixture has been found to give excellent results for this class of work, probably owing to the reduction in the total carbon and to its action in closing the grain.

COEFFICIENT OF FRICTION

There is no data as to the relation between the composition of cast iron and its coefficient of friction. Since graphite is an excellent lubricant it is probable that the percentage of graphite is the controlling factor here, the friction decreasing with increase in this element. From theoretical considerations we should expect the best results to be obtained with a very soft iron low in sulphur, manganese, and combined carbon, and high in graphite.

CASTING PROPERTIES

The properties which remain to be considered pertain more particularly to the casting as a whole and are chiefly

influenced by the design, molding and pouring of the casting, and to a very much less extent, by the composition of the metal.

Unsoundness due to the presence of blowholes and shrinkage cavities, while usually resulting from bad practice in molding may also be caused by poor quality of metal. Blowholes may be caused by oxidized metal or by excessive sulphur. For the avoidance of oxidation see pages 71 and 92. When caused by sulphur the remedy is to decrease this element. Raising the manganese is often effective in preventing blowholes since it acts both as a deoxidizer and desulphurizer. Scott (14) states that manganese below .25% often results in blowholes. High phosphorus sometimes acts as a corrective of blowholes due to its prolonging the fluidity, thus giving the iron more chance to release the dissolved gases. The cause and prevention of shrinkage cavities has been discussed on pages 112 to 107.

Dirty castings are also caused chiefly by poor molding, pouring or cupola practice. Occasionally, however, it may result from wrong composition of the metal, and the points chiefly to be watched are to keep the sulphur low; to avoid kish, or segregated graphite; and to avoid oxidized metal.

Sulphur tends to cause dirty castings because it makes the iron congeal more quickly, and hence any dirt present has less chance to separate. In addition the sulphides of iron and manganese themselves form dirt spots when segregated. Kish is usually caused by too much silicon (see page 57), or sometimes by too much total carbon. Oxidized metal is a prolific source of dirty castings but the oxidation is usually due to bad cupola practice (170) or to use of oxidized scrap. Moderately high manganese and phosphorus are conducive to clean castings, the first because it takes care of sulphur and oxidation and the second because it increases the fluidity of the metal and thus gives the dirt a better chance to float out.

Porosity is usually caused by the presence of kish. (See

preceding paragraph.) Pinholes, another form of porosity, are usually due to excessive sulphur in the form of iron sulphide. This compound retains gases in solution until the metal is partially frozen and then releases them in the form of tiny bubbles which give rise to this defect. Decrease in sulphur or increase in manganese or both is the remedy.

Segregation proper is caused by the difference in melting point and specific gravity of the several constituents of cast iron. The constituents of lowest melting point are the phosphorus and sulphur compounds and it is, therefore, in these cases that we find the greatest tendency towards segregation. It is not usual to find hard spots in heavy castings high in phosphorus which are caused by the phosphide being squeezed out into blowholes formed during solidification. Frequently the phosphide does not completely fill the cavity, or fill it as a loose globule. The sulphides, owing to their low specific gravity usually segregate in the top of the casting and it is not infrequent to find several times the normal amount of sulphur in the upper part of heavy castings. Manganese sulphide segregates more readily than iron sulphide. (See page 61.)

Besides segregation proper we sometimes find cases of non-homogeneity due to other causes. Occasionally spots of white iron are found in the interior of castings. It has always been difficult to account for these but the clew is given by the fact that they are invariably found in castings poured from the first metal tapped. Undoubtedly they are caused by the iron boiling on the sand bed and are connected in some way with the partial Bessemerizing of the metal. Again, hard spots in castings are sometimes due to small pieces of metal (as for example, small steel scrap and shot iron) being incompletely melted in their passage through the cupola. Ferro manganese and other ferro alloys may give rise to this same trouble through incomplete solution when stirred into the ladle.

Crystallization in cast iron is an important subject but one which need not receive attention here, since, as a source

of weakness, it is influenced by the design of the casting rather than by the composition of the metal (172, chap. 4).

Shrinkage strains are caused primarily by wrongly designed castings but the trouble may be aggravated by the composition of the metal. High sulphur is a particularly prolific source of internal stresses and, in general, the greater the total shrinkage the greater the strains due to this cause. The relation of composition to total shrinkage is discussed on page 111.

As all foundrymen know, the fineness of finish and smoothness of skin of a casting depend chiefly on the sands and facings used and the skill of the molder. High phosphorus in the iron, however, is a considerable aid in getting the fine skin desired in ornamental work. Another element which affects the skin is manganese which has the rather peculiar action of causing the sand to peel from the castings with extreme readiness. With 1% manganese this tendency is evident and with 2% it is very marked.

PART III

CHEMICAL STANDARDS FOR IRON CASTINGS

Under this heading is presented what is probably the largest collection of analyses of iron castings ever gathered into one table, and it is thought that the information contained should be of considerable value and interest.

The sources of this data are three in number: first, published work; second, the private notes of the writer; third, the replies to the inquiries sent out by your committee.

Regarding this last source, which has supplied the greater number of analyses, approximately 1,000 inquiries were sent out to as many different foundries, selected largely at random from "Penton's List." These inquiries ran in substance as follows:

"At the last convention of the A. F. A. it was decided to make an attempt to formulate chemical standards for iron castings, in the belief that such standards would be of great use both to the individual foundryman and to the industry as a whole.

"The information on which these should be based could, of course, be obtained by analyzing typical castings bought in the open market. This would, however, involve much trouble and expense, and will be unnecessary if foundrymen will freely donate the information for the good of the industry.

"We urge you, therefore, to act generously in giving us the data indicated below, and since composition is but one item in the successful manufacture of castings, we feel sure that in so doing there can be no possible detriment to your personal interests.

"Replies will, of course, be entirely confidential as regards the names of those giving information. There is desired the following information:

"Name or Class of Castings, Silicon, Sul., Phos., Mang., Comb. Carb., Graph. Carb., Total Carb."

To this letter about 10 per cent. of replies were received, the greater number of which contained more or less information.

Regarding the classification of castings, it is evidently impossible to consider as separate cases all the different patterns. Nor would this be desirable, since any foundry must itself class its castings into comparatively few groups which are each poured from one kind of iron. For example, a shop doing machine-tool work may make castings from several hundred patterns and will use not to exceed four mixtures of iron for all of these, probably dividing the work into light, medium and heavy castings, with possibly a special mixture for pulleys. It is thought, therefore, that a classification according to use or properties necessary is in the majority of cases desirable.

Thickness is, of course, taken into consideration, since this largely determines the percentage of silicon necessary, and it has been the aim to subdivide the various classes according to section wherever possible. In this respect the writer has endeavored to follow the definitions of the American Society for Testing Materials, who have grouped castings according to thickness as follows: (126).

"Castings having any section less than one-half of an inch thick shall be known as light castings."

"Castings in which no section is less than 2 inches thick shall be known as heavy castings."

"Medium castings are those not included in the above definitions."

It is unfortunately true that there is much lacking in this table, many important classes of castings being entirely missing, while others are inadequately represented by only one or two analyses. These deficiencies are due to the lack of available data in certain cases, and it is to be hoped that they may be at least partially remedied by future work.

Malleable cast iron is omitted entirely, partly because of the small amount of data obtained and partly because its manufacture is a process entirely different from those involved in the ordinary iron foundry.

Regarding arrangement, the analyses taken from published sources are preceded by a number in the first column referring to the bibliography, Part V. The last analysis under each head is preceded by the word "Sug." (abbreviated from suggested) and is the tentative standard or probable best analysis *suggested* by your committee. It should be clearly understood in this connection that while this is based on careful study of both theory and practice, it represents only the individual opinion of the writer, and is not necessarily infallible.

Furthermore, these suggestions are incomplete in certain other respects. The most desirable percentage of silicon, for example, will depend largely on the exact thickness of the casting and the practice followed in shaking out. These factors, being in many cases undetermined, have been allowed for by giving fairly wide limits to this element. Again, the possibilities in the use of purifying alloys have not been taken into account here, although they have been discussed in the preceding parts, and the use of steel scrap has been ignored except that the "low" total carbon specified in some cases must, as a rule, be obtained in this way. Finally in many cases, a very wide range of composition is permissible and compatible with the best results, and in such cases the question of cost will be the first element to be considered in fixing the composition.

Acid Resisting Castings

Ref.	Silicon	Sulphur	Phos	Mang.	Comb. Carb.	Total Carb.
7	1.00%	.050%	.50%			3.00%
42	2.30	low	.20	.41%		3.60
81	.80-2.00	.02-.03	.40-.60	1.00-2.00		3.00-3.50
Sug.	1.00-2.00	und. .05	und. .40	1.00-1.50		3.00-3.50

Acid Stills and Eggs. See Acid Resisting Castings

Note: "und." is abbreviated from under and "sug." from suggested.

Agricultural Machinery, Ordinary

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb
64	2.20-2.80%	und. .085%	und. .70%	und. .70%		
	2.65	.050	.81	.70	.15%	3.50%
	2.25	.070	.70	.80	.30	3.50
	2.10	.068	.73	.45	.47	3.42
	2.00	.089	.89	.46	.50	3.39
Sug.	2.00-2.50	.06-.08	.60-.80	.60-.80		

Agricultural Machinery, Very Thin

	2.90%	.050%	.85%	.70%	.10%	3.50%
	2.50	.080	.65	.60	.30	3.50
Sug.	2.25-2.75	.06-.08	.70-.90	.50-.70		

Air Cylinders

64	1.20-1.50%	und. .09%	.35-.60%	.50-.80%		
	1.90	.074	.50	.65		
	1.12	.085	.40	.70	.70%	3.50%
	.95	.100	.30	.90	.80	3.40
	2.00	.070	.30	.60	.40	
Sug.	1.00-1.75	und. .09	.30-.50	.70-.90		3.00-3.30

Ammonia Cylinders

14	1.20-1.90%	und. .095%	und. .70%	.60-.80%		
Sug.	1.00-1.75	und. .09	.30-.50	.70-.90		3.00-3.30%

Annealing Boxes for Malleable Casting Work

Sug.	.65%	.05%	.10-.20%	.20%	2.75%	2.75%

Annealing Boxes, Pots and Pans

171	1.20%	.060%	.10%	.40%		
81	1.80	.03	.70	.60		2.90%
198	1.53	.04	.33	1.08	.58	3.68
Sug.	1.40-1.60	und. .06	und. .20	.60-1.00		low

Automobile Castings

	1.80%	.030%	.50%	.70%	.60%	3.50%
	1.65	.076	.45	.65	.55	
	2.35	.072	.60	.70	.40	
Sug.	1.75-2.25	und. .08	.40-.50	.60-.80		

Note: "und." is abbreviated from under and "sug." from suggested.

Automobile Cylinders

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.65%	.076%	.45%	.65%	.55%	
19	2.31	.094	.50	.43	.51	3.35%
19	2.70	.053	.46	.23	.44	3.02
19	2.45	.102	.72	.41	.41	3.47
19	2.59	.083	.57	.47	.11	3.35
19	2.55	.104	.82	.32	.09	3.04
19	2.98	.047	.89	.27	.14	3.19
19	2.67	.111	.73	.38	.10	3.24
19	2.30	.084	.81	.52	.59	3.35
19	1.60	.083	.54	.42	.66	3.75
19	3.26	.159	.93	.44	.03	2.87
19	1.72	.091	.58	.48	.62	2.52
19	1.67	.068	.44	.82	.62	3.91
19	1.38	.093	.62	.52	.76	3.61
19	1.47	.075	.13	.60		
19	1.50	.103	.86	.43		
19	1.99	.130	.65	.39	.45	3.17
19	1.89	.090	.70	.39	.77	3.34
19	2.29	.090	.83	.60	.90	4.16
Sug.	1.75-2.00	und. .08	.40-.50	.60-.80	.55-.65	3.00-3.25

Automobile Fly Wheels

	2.35%	.072%	.60%	.70%	.40%
	3.10	.045	.35	.55	.27
Sug.	2.25-2.50	und. .07	.40-.50	.50-.70	

Balls for Ball Mills

196	1.00%	.100%	.30%	.50%		low
Sug.	1.00-1.25	und. .08	und. .20	.60-1.00		low

Bed Plates

	2.20%	.090%	.55%	.50%		
	1.32	.090	.40	.60		
	1.65		.28	.92	.72%	
	1.85	.080	.60	.55	.50	3.25-3.50%
	1.80-2.20	.04-.06	.45-.55	.40-.50	.40-.50	3.40-3.60
	1.65-1.85	.070	.65-.80	.60-.75		3.85
Sug.	1.25-1.75	und. .10	.30-.50	60-.80		

Binders. See Agricultural Machinery

Note: "und." is abbreviated from under and "sug." from suggested.

Boiler Castings

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
194	2.50%	und. .07%	und. .20%	.80-1.0%		
	2.25	.060	.62	.59		
Sug.	2.00-2.50	und. .06	und. .20	.60-1.0		

Brake Shoes

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
95	1.50%		low			low
64	2.00-2.50	und. .15%	und. .70%	und. .70%		
57	2.00-2.50	und. .15	und. .70	und. .70		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65%	3.50%
	1.86	.183	1.93	.33	1.22	3.01
Sug.	1.40-1.60	.08-.10	.30	.50-.70		low

Car Castings, Gray Iron. See also BRAKE SHOES AND CAR WHEELS

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
64	2.20-2.80%	und. .085%	und. .70%	und. .70%		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65%	3.50%
	2.25	.050	.60	.75		3.50
	1.75	.070	.85	.60		
Sug.	1.50-2.25	und. .08	.40-.60	.60-.80		

Car Wheels, Chilled

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
51	.50-.70%	.05-.07%	.35-.45%	.30-.50%	.50-.75%	3.50%
171	.58-.68	.05-.08	.25-.45	.15-.27	.63-1.0	
171	.73	.080	.43	.44	1.25	4.31
171	.86	.127	.35	.49	.92	3.47
126	.70	.08	.50	.40	.60	3.50
	.58	.141	.38	.48	.90	3.63
	.57	.101	.41	.42		
	.68	.188	.36	.53		
	.67	.170	.38	.81	.74	3.66
	.50-.60	.08-.10	.30-.40	.45-.55	.70-.80	3.50
Sug.	.60-.70	.08-.10	.30-.40	.50-.60	.60-.80	3.50-3.70

Car Wheels, Unchilled. See WHEELS

Chemical Castings. See ACID RESISTING CASTINGS

Chilled Castings

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
135	.80-1.00%	.09-.11%	.50%	.50%		
197	1.20-1.40		low			low
69	1.00	.08	.40	.75		3.25%
65	1.35	.117	.60	.54	.65%	3.00
	.50	.200	.45	1.50	3.00	3.00
	1.20	.090	.30	.50	1.20	3.20
	1.20	.080	.30	1.25		3.50
	.75	.090	.30	.30	3.00	3.20
Sug.	.75-1.25	.08-1.0	.20-.40	.80-1.2		

Note: "und." is abbreviated from under and "sug." from suggested.

Chills

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
105	2.07%	.073%	.31%	.48%	.23%	2.64%
Sug.	1.75-2.25	und. .07	.20-.40	.60-1.0		

Collars and Couplings for Shafting

	1.60%	.040%	.55%	.55%	.30%	3.57%
Sug.	1.75-2.00	und. .08	.40-.50	.60-.80		

Cotton Machinery. See also MACHINERY CASTINGS

	2.20-2.30%	und. .09%	.70%	.60%	.45%	3.45%
Sug.	2.00-2.25	und. .08	.60-.80	.60-.80		

Crusher Jaws

135	.80-1.00%	.09-.11%	.50%	.50%		
69	1.00	.080	.40	.75		3.25%
	.50	.20	.45	1.50	3.00%	3.00
Sug.	.80-1.00	.08-.10	.20-.40	.80-1.2		

Cutting Tools, Chilled Cast Iron

65	1.35%	.117%	.60%	.54%	.65%	3.00%
Sug.	1.00-1.25	und. .08	.20-.40	.60-.80		

Cylinders. See AIR CYLINDERS, AMMONIA CYLINDERS, AUTOMOBILE CYLINDERS, GAS ENGINE CYLINDERS, HYDRAULIC CYLINDERS, LOCOMOTIVE CYLINDERS, STEAM CYLINDERS.

Cylinder Bushings, Locomotive. See LOCOMOTIVE CASTINGS, HEAVY

Dies for Drop Hammers

171	1.40%	.060%	.10%	.40%		
	1.40	.090	.40	.70	1.00%	3.20%
Sug.	1.25-1.50	und. .07	und. .20	.60-.80		low

Diamond Polishing Wheels

105	2.70%	.063%	.30%	.44%	1.60%	2.97%

Dynamo and Motor Frames, Bases and Spiders, Large

171	1.95%	.042%	.40%	.39%	.59%	3.82%
	1.90	.08	.47	.60	.64	3.79
	2.15	.070	.75	.60	.55	3.80
	2.10	.070	.55	.40		3.50
Sug.	2.00-2.50	und. .08	.50-.80	.30-.40	.20-.30	low

Note: "und." is abbreviated from under and "sug." from suggested.

Dynamo and Motor Frames, Bases and Spiders, Small

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	3.19%	.075%	.89%	.35%	.06%	2.95%
	2.30	.070	.55	.40		3.50
	2.50	.070	.75	.60	.55	3.95
Sug.	2.50-3.00	und. .08	.50-.80	.30-.40	.20-.30	low

Electrical Castings

171	3.19%	.075%	.89%	.35%	.06%	2.95%
171	1.95	.042	.40	.39	.59	3.82
	1.90	.080	.47	.60	.64	3.79
	2.15	.070	.75	.60	.55	3.80
	2.50	.070	.75	.60	.55	3.95
	2.10	.070	.55	.40		3.50
	2.30	.070	.55	.40		3.50
Sug.	2.00-3.00	und. .08	.50-.80	.30-.40	.20-.30	low

Eccentric Straps. See Locomotive Castings and Machinery Castings

Engine Castings. See Bed Plates, Fly Wheels, Machinery Castings, Engine Frames, Locomotive Castings, Steam Cylinders.

Engine Frames. See also Machinery Castings

	2.25%	.080%	.55%	.60%
	1.60	.090	.50	.60
	1.32	.100	.40	.60
Sug.	1.25-2.00	und. .09	.30-.50	.60-1.0

Fans and Blowers. See Machinery Castings

Farm Implements

	2.00%	.089%	.89%	.46%	.50%	3.39%
	2.10	.068	.68	.45	.47	3.32
Sug.	2.00-2.50	.06-.08	.50-.80	.60-.80		

Fire Pots

194	2.50%	und. .07%	und. .20%	.80-1.0%		
Sug.	2.00-2.50	und. .06	und. .20	.60-1.0		low

Fly Wheels. See also Automobile Fly Wheels and Machinery Castings

	2.20%	.090%	.55%	.50%
	1.50	.090	.50	.60
Sug.	1.50-2.25	und. .08	.40-.60	.50-.70

Note: "und." is abbreviated from under and "sug." from suggested.

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
Friction Clutches						
64	2.00-2.50%	und. .15%	und. .70%	und. .70%		
Sug.	1.75-2.00	.08-.10	und. .30	.50-.70		low
Furnace Castings						
194	2.50%	und. .07%	und. .20%	.80-1.0%		
	2.00	.085	.35	.53		
	1.85	.090	.70	.60		
Sug.	2.00-2.50	und. .06	und. .20	.60-1.00		low
Gas Engine Cylinders						
137	1.45%			.65%		
	1.98	.090%	.84%	.63		
	1.21	.117	.40	.35	1.40%	3.74%
	1.00-1.25	.04-.08	20-.40	.70-.80	.60-.80	3.00-3.10
Sug.	1.00-1.75	und. .08	.20-.40	.70-.90		3.00-3.30
Gears, Heavy						
171	1.40%	.060%	.10%	.40%		
	.94	.150	.43	.31	1.47%	
	1.60	.080	.40	.60		3.50%
	1.50-1.75	.080	.40-.60	.50-.70		
	1.00-1.25	.075	.40	.80-1.0		very low
	1.40-1.60	.04-.08	.30-.50	.40-.60	.50-.80	3.20-3.40
Sug.	1.00-1.50	.08-.10	.30-.50	.80-1.0		low
Gears, Medium						
64	1.50-2.00%	und. .08%	.35-.60%	.50-.80%		
171	1.90	.060	.10	.40		
	2.30	.060	.60	.60		3.75%
	1.90	.100	.69	.58	.55%	3.83
Sug.	1.50-2.00	und. .09	.40-.60	.70-.90		
Gears, Small						
198	3.43%		1.42%	.90%		
	2.00	.100%	.50	.70		3.50%
Sug.	2.00-2.50	und. .08	.50-.70	.60-.80		
Grate Bars						
195	2.75%	low	low			
	2.00	.085%	.35%	.53%		
Sug.	2.00-2.50	und. .06	und. .20	.60-1.0	und. .30	low

Note: "und." is abbreviated from under and "sug." from suggested.

Grinding Machinery, Chilled Castings for

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	.50%	.200%	.45%	1.50%	3.00%	3.00%
Sug.	.50-.75	.15-.20	.20-.40	1.5-2.0		

Gun Carriages

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	.94%	.050%	.44%	.31%	.63%	3.03%
171	1.00	.050	.30	.60	1.10	2.50
Sug.	1.00-1.25	und. .06	.20-.30	.80-1.0		low

Gun Iron

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.34%	.003%	.08%	1.00%	.93%	3.12%
171	1.19	.055	.41	.42	1.13	3.18
171	1.53	.050	.29	.45	.42	3.43
171	.98	.06	.43	.43	.75	1.74
198	.30		.44	3.55	1.70	3.90
	1.20	.100	.30	.80	1.00	3.00
Sug.	1.00-1.25	und. .06	.20-.30		.80-1.0	low

Hangers for Shafting

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.60%	.040%	.55%	.55%	.30%	3.57%
Sug.	1.50-2.00	und. .08	.40-.50	.60-.80		

Hardware, Light

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
198	1.84%		.58%	1.04%		
198	2.20		.74	1.10		
198	2.50		1.21	1.16		
	2.51	.110%	.62	.41	.24%	3.18%
	2.70	.030	.60	.50	.40	3.60
	2.50	und. .050	.60	.70		
	2.00-2.25	.050	.85	.40		3.85-4.00
Sug.	2.25-2.75	und. .08	.50-.80	.50-.70		

Heat Resistant Iron

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.20%	.060%	.10%	.40%		
171	1.67	.032	.09	.29	.43%	3.87%
134	2.15	.086	1.26	.41	.13	3.30
134	2.02	.070	.89	.29	.84	3.60
198	1.53	.040	.33	1.08	.58	3.68
105	2.07	.073	.31	.48	.23	2.64
81	1.80	.030	.70	.60		
195	2.75	low	low			
194	2.50	und. .07	und. .20	.80-1.0		
	1.76	.075	.63	.79	.56	3.68
	2.00	.030	.70			
Sug.	1.25-2.50	und. .06	und. .20	.60-1.00	und. .30	low

Note: "und." is abbreviated from under and "sug." from suggested.

Hollow Ware

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	2.51%	.110%	.62%	.41%	.24%	3.18%
Sug.	2.25-2.75	und. .08	.50-.70	.50-.70		

Housings for Rolling Mills

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.00-1.25%	.085%	.65%	.75%		low
Sug.	1.00-1.25	und. .08	.20-.30	.80-1.0		low

Hydraulic Cylinders, Heavy

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.00%	.050%	.30%	.60%	1.10%	2.50%
22	.90	.136	.39	.25	1.44	3.34
63	.80-1.50	.07-.11	.35-.50			
	1.12	.085	.40	.70	.70	3.50
	.95	.100	.30	.90	.80	3.40
	1.15	und. .08	.50	.60	1.15	
	.90-1.20	.06-.08	.30-.50	.80-1.0	.80-1.0	2.90-3.10
Sug.	.80-1.20	und. .10	.20-.40	.80-1.0		low

Hydraulic Cylinders, Medium

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.40%	.060%	.10%	.40%		
	1.90	.074	.50	.65		
	1.62	.08	.50	.60		
	1.75	.070	.40	.55	.50%	
Sug.	1.20-1.60	und. .09	.30-.50	.70-.90		low

Ingot Molds and Stools

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.20%	.060%	.10%	.40%		
171	1.67	.032	.09	.29	.43%	3.87%
Sug.	1.25-1.50	und. .06	und. .20	.60-1.0		

Locomotive Castings, Heavy

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
57	1.40-2.00%	und. .085%	und. .60%	und. .70%		
	1.25-1.50	.06-.08	.40-.60	.45-.60	.50-.70%	3.50%
	1.62	.098	.40	.49		
Sug.	1.25-1.50	und. .08	.30-.50	.70-.90		

Locomotive Castings, Light

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
57	1.40-2.00%	und. .085%	und. .60%	und. .70%		
	1.50-2.00	.06-.08	.40-.60	.45-.60	.45-.55%	3.50%
Sug.	1.50-2.00	und. .08	.40-.60	.60-.80		

Note: "und." is abbreviated from under and "sug." from suggested.

Locomotive Cylinders

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
126	1.25-1.75%	und. .10%	und. .90%			
57	1.40-2.00	und. .085	und. .60	und. .70%		
	1.25-1.50	.06-.08	.40-.60	.45-.60	.50-.70%	3.50%
	1.00-1.40	und. .11	.40-.90	.40-.90		
	1.41	.092	.38	.39		
	1.56	.061	.45	.78		
Sug.	1.00-1.50	.08-.10	.30-.50	.80-1.0		

Locks and Hinges. See Hardware, Light

Machinery Castings, Heavy

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.05%	.110%	.54%	.35%	.33%	2.98%
178	.85	.030	.35	.92		
63	.80-1.50	.030-.050	.35-.50			
	.90-1.50	.09-1.2	.15-.40	.20-.80	.10-.30	2.50-2.90
	1.85	.100	.50	.60		3.50
	1.30	.090	.40	.60		
	1.85	.120	.60	.45		3.40-3.55
	1.75	.100	.50	.70	.80	3.65
Sug.	1.00-1.50	und. .10	.30-.50	.80-1.0		low

Machinery Castings, Medium

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	1.83%	.078%	.50%	.31%	.43%	2.93%
	2.25	.080	.55	.60		
	1.60	.060	.66			
	2.29	.071	.66	.49		
	1.60	.090	.50	.60		
	2.10	.110	.67	.50		3.40-3.55
	2.25	.060	.75	.55		
	2.00	.100	.75	.50	.75	3.50
	1.76	.075	.63	.79	.56	3.68
	2.00	.100	.50	.50	.50	3.60
	2.35	.075	.45	.65	.30	
	1.80	.060	.80	.50	.70	
	2.06	.075	.78	.47		3.45
	1.40	low	.20	.40		
	2.00	.030	.70			
	1.85	.08	.60	.50-.60	.50	3.25-3.50
	1.50-2.10	.08-.09	.40-.80	.20-.60	.10-.40	2.60-3.20
	1.80-2.10	und. .09	.40-.90	.40-.90		
Sug.	1.50-2.00	und. .09	.40-.60	.60-.80		

Note: "und." is abbreviated from under and "sug." from suggested.

Machinery Castings, Light

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	2.04%	.044%	.58%	.39%	.32%	3.84%
	2.25	.080	.70	.50	.20	3.55
	2.76	.037	1.19		.13	3.66
	2.49	.097	.90	.42		3.40
	2.51	.084	.62	.61		3.46
	2.50	.100	.60	.70		3.50
	3.00	.060	.65	.50		3.50
	2.40	.050	.47	.59		
	2.85	.064	.67	.65		
	2.52	.062	.66	.68		
	3.15	.050				
	2.50	.100	.70	.60		3.40-3.55
	2.20-2.80	.06-.08	.60-1.3	.20-.40	.10-.60	3.00-3.60
Sug.	2.00-2.50	und. .08	.50-.70	.50-.70		

Machine Tool Castings. See MACHINERY CASTINGS

Motor Frames, Bases and Spiders. See DYNAMO

Molding Machines. See MACHINERY CASTINGS

Mowers. See AGRICULTURAL MACHINERY

Niter Pots. See ACID RESISTING CASTINGS AND HEAT RESISTING CASTINGS

Ornamental Work

171	4.19%	.080%	1.24%	.67%	.03%	2.88%
	2.51	.110	.62	.41	.24	3.18
	2.25		.60-.90			
Sug.	2.25-2.75	und. .08	.60-1.0	.50-.70		

Permanent Molds

134	2.15%	.086%	1.26%	.41%	.13%	3.30%
134	2.02	.070	.89	.29	.84	3.60
Sug.	2.00-2.25	und. .07	.20-.40	.60-1.0		

Permanent Mold Castings

93	2.00-3.00%					3.00-4.00%
	1.50-3.00	und. .06		und. .40		

Note: "und." is abbreviated from under and "sug." from suggested.

Piano Plates

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
197	2.00%	low	.40%	.60%		
Sug.	2.00-2.25	und. .07	.40-.60	.60-.80		

Pillow Blocks

	1.60%	.040%	.55%	.55%	.30%	3.50%
Sug.	1.50-1.75	und. .08	.40-.50	.60-.80		

Pipe

	2.00%	.060%	.60%	.60%		
	2.00	.060	1.00	.60		
Sug.	1.50-2.00	und. .10	.50-.80	.60-.80		

Pipe Fittings

198	2.88%		.41%	1.10%		
	1.70	.058	.50	.73	1.16	4.18
	2.51	.110	.62	.41	.24	3.18
Sug.	1.75-2.50	und. .08	.50-.80	.60-.80		

Pipe Fittings for Superheated Steam Lines

75	1.72%	.085%	.89%	.48%	.17%	2.45%
75	1.40-1.60	.06-.09	.20-.40	.45-.75		3.00-3.25
Sug.	1.50-1.75	und. .08	.20-.40	.70-.90		low

Piston Rings

137	1.35%			.40%		
	1.60	.08%	1.15%	.35	.60%	
	1.50-2.00	.06-.08	.40-.60	.45-.60	.45-.55	3.50
Sug.	1.50-2.00	und. .08	.30-.50	.40-.60		low

Plow Points, Chilled

197	1.20-1.40%		low			low
	1.20	.090%	.30%	.50%	1.20%	3.20%
	.75	.090	.30	.30	3.00	3.20
	1.20	.080	.30	1.25		3.50
Sug.	.75-1.25	und. .08	.20-.30	.80-1.0		

Printing Presses. See MACHINERY CASTINGS

Note: "und." is abbreviated from under and "sug." from suggested.

Propeller Wheels

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.15%		.32%	.51%	.60%	
	1.40	low	.20	.40		
Sug.	1.00-1.75	und. .10%	.20-.40	.60-1.0		low

Pulleys, Heavy

	1.75%	.040%	.55%	.55%	.30%	3.57%
	2.40	.060	.60	.60		3.75
Sug.	1.75-2.25	und. .09	.50-.70	.60-.80		

Pulleys, Light

64	2.20-2.80%	und. .08%	und. .70%	und. .70%		
14	2.40	und. .08	.95	.70		
	2.72	.040	.50	.66		
	2.52	.075	.77	.68		3.37%
	3.35	.089	.70	.47		3.42
	2.25	.040	.55	.55	.30	3.57
	2.15	.080	.70	.60	.40	3.55
Sug.	2.25-2.75	und. .08	.60-.80	.50-.70		

Pumps, Hand

	2.30-2.75%	und. .08%	.60-1.0%	.30-.50%		
Sug.	2.00-2.25	und. .08	.60-.80	.50-.70		

Radiators

	2.15%	low	.80%	.45%	.50%	3.50%
	2.45	.104%	.44	.40	.35	3.40
Sug.	2.00-2.25	und. .08	.60-.80	.50-.70	.50-.60	

Railroad Castings

64	2.20-2.80%	und. .08%	und. .70%	und. .70%		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65%	3.50%
	2.25	.050	.60	.75		
	1.75	.070	.85	.60		
Sug.	1.50-2.25	und. .08	.40-.60	.60-.80		

Retorts. See HEAT RESISTANT CASTINGS

Rolls, Chilled

171	.50-1.00%	.01-.06%	.20-.80%	.15-1.5%	2.60-3.25%	
171	.80	.100	.88	.16	.91	2.84%
171	.71	.058	.54	.39	1.38	3.00
173	.65	.050	.25	1.50	.63	3.50
Sug.	.60-.80	.06-.08	.20-.40	1.0-1.2		3.00-3.25

Note: "und." is abbreviated from under and "sug." from suggested.

Rolls, Unchilled (sand cast)

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
171	.75%	.030%	.25%	.66%	1.20%	4.10%

Scales

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
198	1.67%		1.92%	1.90%		
198	2.12		.61	.80		
198	1.70		.63	1.60		
Sug.	2.00-2.30	und. .08	.60-1.0	.50-.70		

Slag Car Castings

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.76%	.075%	.63%	.79%	.56%	3.68%
	2.00	.030	.70			
Sug.	1.75-2.00	und. .07	und. .30	.70-.90		

Smoke Stacks, Locomotive. See Locomotive Castings

Soil Pipe and Fittings

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	2.00%	.060%	1.00%	.60%		
Sug.	1.75-2.25	und. .09	.50-.80	.60-.80		

Steam Cylinders, Heavy

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.41%	.092%	.38%	.39%		
	.95	.100	.30	.90	.80%	3.40%
	1.10	.136	.43	.33	.99	3.30
	1.00	.080	.20-.30	1.00	.75	3.00
	1.35-1.50	.080	.50	.75		3.65
	1.20-1.40	.04-.08	.40-.50	.70-.80	.70-.80	3.00-3.20
111	.90-1.20	.09-.12	.20-.40	.70-.90		und. 3.50
Sug.	1.00-1.25	und. .10	.20-.40	.80-1.0		low

Steam Cylinders, Medium

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
70	1.66%	.065%	.70%	.90%		
70	1.60	.063	.72	.85		
70	1.70	.070	.70	.75		
70	1.70	.075	.60	.92		3.50%
14	1.40-2.00	.085	.70	.30-.70		
64	1.50-2.00	und. .08	.35-.60	.50-.80		
	1.40-1.60	und. .09	.40-.90	.40-.90		
	1.50-1.65	.080	.60	.60-.70		
	1.50-1.80	.070	.43	.76		

Note: "und." is abbreviated from under and "sug." from suggested.

Steam Cylinders, Medium—*Continued*

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.85%	.080%	.60%	.50-.60%	.50%	3.25-3.50%
	1.75	.100	.65	.55		3.40-3.55
	1.32	.136	.43	.33	.99	3.30
	1.12	.085	.40	.70	.70	3.50
	2.00	.100	.50	.70	.40	3.50
	2.00	.070	.30	.60		
	1.50	.070	.75	.70		3.50
	1.59	.109	.60	.38		3.34
	1.86		.29	.55	.52	
	1.90	.074	.50	.65		
	1.56	.061	.45	.78		
Sug.	1.25-1.75	und. .09	.30-.50	.70-.90		

Steam Chests. See LOCOMOTIVE CASTINGS AND MACHINERY CASTINGS

Stove Plate

198	2.90%		.73%	1.40%		
171	2.59	.072%	.62	.37	.35%	3.30%
171	3.19	.084	1.16	.38	.33	3.41
	2.75	.050	1.00	.80	.18	3.38
	2.79	.077	1.40	.32	.20	3.22
	2.51	.110	.62	.41	.24	3.18
	2.76	.071	.63	.63	.37	3.50
	2.76	.084	.65	.54		
	2.50	.060	1.00	.60		
	2.60	.050	.60	.60		
	2.50-3.00	und. .10	.60-.80	.40-.60		3.00-4.00
Sug.	2.25-2.75	und. .08	.60-.90	.60-.80		

Valves, Large

64	1.20-1.50%	und. .09%	.35-.60%	.50-.80%		
136	1.00	.100	.50	.90		
	1.67		.26	.45	.69%	
Sug.	1.25-1.75	und. .09	.20-.40	.80-1.0		

Valves, Small

	1.70%	.058%	.50%	.74%	1.16%	4.18%
	2.23	.075	.67	.67		
Sug.	1.75-2.25	und. .08	.30-.50	.60-.80		low

Valve Bushings. See LOCOMOTIVE CASTINGS AND MACHINERY CASTINGS

Note: "und." is abbreviated from under and "sug." from suggested.

Water Heaters

Ref.	Silicon	Sulphur	Phos.	Mang.	Comb. Carb.	Tota Carb
	2.15%	.050%	.40%	.50%		
Sug.	2.00-2.25	und. .08	.30-.50	.60-.80		

Weaving Machinery. See MACHINERY CASTINGS

Wheels, Large

	2.10%	.040%	.40%	.70%
Sug.	1.50-2.00	und. .09	.30-.40	.60-.80

Wheels, Small

	2.10%	.050%	.40%	.50%
	1.60	.083	.60	.39
Sug.	1.75-2.00	und. .08	.40-.50	.50-.70

Wheel Centers. See LOCOMOTIVE CASTINGS

White Iron Castings

	.50%	.150%	.20%	.17%	2.90%	
	.90	.250	.70	.50		2.50

Wood Working Machinery. See MACHINERY CASTINGS

Note: "und." is abbreviated from under and "sug." from suggested.

PART IV

DIRECTORY OF PIG IRON BRANDS

As an introduction to this section a brief description and discussion of the methods used for grading pig iron may be of service.

Pig iron may be classified from several points of view. According to the furnace practice it is cold, warm or hot blast iron. On the basis of the fuel used in its manufacture it is coke, anthracite, or charcoal pig. According to the method of casting it is sand, chill or machine cast. Finally, according to its chemical composition it is basic, Bessemer, malleable, foundry or forge iron. To completely describe any given brand we must classify it in all four ways; thus for example, we might say of a certain iron that it was hot blast, coke chilled, basic.

The terms used in the first three classifications hardly need definition since they are self-explanatory. With regard to the last it may be well for the sake of completeness to define these grades.

Basic iron means primarily a low silicon iron, the standard for this grade having silicon under 1%, and sulphur under .050%.

Similarly, Bessemer iron means primarily phosphorus under .10%. Standard Bessemer contains 1.00-1.25% silicon, with sulphur under .050%, but the grade is essentially based on low phosphorus. Irons with extra low phosphorus and variable silicon sometimes go under the designation of "low phosphorus" iron.

Finally, the terms foundry and forge embrace practically everything in the way of ordinary iron, these grades being subdivided again on the basis of silicon and sulphur content.

The following subclassification of foundry and forge iron has been agreed upon by the blast furnace interests of the districts indicated:

CLASSIFICATION AND GRADES OF FOUNDRY IRON

	Silicon	*Sulphur*
Southern Points		
No. 1 Foundry	2.75 – 3.25%	.05% and under
No. 2 "	2.25 – 2.75	.05 " "
No. 3 "	1.75 – 2.25	.06 " "
No. 4 "	1.25 – 2.00	.07 " "
Gray Forge	1.25 – 1.75	.08 " "
No. 1 Soft	3.00 and over	.05 " "
No. 2 Soft	2.50 – 3.25	.05 " "
Eastern Points		
No. 1 X	2.75 and up	.030 and under
No. 2 X	2.25 – 2.75	.045 " "
No. 2 Plain	1.75 – 2.25	.050 " "
No. 3 Foundry	1.25 – 1.75	.065 " "
No. 2 Mill	1.25 and under	.065 " "
Gray Forge	1.50 " "	065 " up
Mottled and White by Fracture		
Central West & Lake Points		
No. 1 Foundry	2.25 – 2.75%	.05% and under
No. 2 "	1.75 – 2.25	.05 " "
No. 3 "	1.75 and under	.05 " "
Gray Forge		.05 " over
Buffalo Grading		
Scotch	3.00 and over	.05 and under
No. 1 Foundry	2.50 – 3.00	.05 " "
No. 2 "	2.00 – 2.50	.05 " "
No. 2 Plain	1.50 – 2.00	.05 " "
No. 3 Foundry	1.50 (under)	.05 " "
Gray Forge		.05 " (over)

NOTE.—If sulphur is in excess of maximum, it is graded as lower grade, regardless of silicon.

Charcoal is not as a rule graded according to the above table but is sold by fracture, by analysis, by chill tests, or by some special system of grading according to the custom of the maker and demand of the purchaser.

It will be noted that so far as foundry iron is concerned the grading system is based exclusively on silicon and sulphur. One reason for this is that the phosphorus and manganese are

fixed by the composition of the ores used, whereas the silicon and sulphur can be varied at will by slight changes in the method of operating the furnace. Since in many, perhaps the majority of, cases a blast furnace will be limited to a very few ores as a source of supply, it follows that it will be limited also in the range of phosphorus and manganese in the iron it produces. For this reason, a given brand of iron will usually run fairly constant as regards phosphorus and manganese, although its silicon and sulphur can be varied at the wish of the management. However, this condition, while common, is not universal, for some concerns possess a variety of ores and can by mixing them produce iron of any composition desired.

In the light of the preceding discussion it is evidently useless to attempt to give the analysis of the various brands within close limits. Especially is this the case with silicon and sulphur which, for foundry irons, can be assumed to be within the limits shown in the grading table previously quoted.

As many foundrymen know, chemical composition is not everything. Questions of blast, fuel, ores, and furnace practice are all important, although unfortunately the exact relationship between these factors and quality is not yet thoroughly understood. It is partly with the idea of furthering investigations along these lines that data on these points is included here.

In using this directory please bear in mind that it is not infallible. Much of the data has been difficult to get, a few concerns refusing absolutely to furnish information. Again, in some cases time brings changes in ownership and character of ore supply, etc., and of course, these things will affect the character of the product. In spite of these deficiencies, however, it is believed that the following tables represent the most accurate information along these lines available at the present time and that they will be found of considerable value.

Finally, it must be emphasized that the use of the data

is not to tell the foundryman the exact analysis of any carload of any brand, but rather to help him locate those brands which have, or can be made to have a composition suitable for his work.

In these tables the percentage of sulphur is not usually given. It should be understood that all furnaces strive for, and usually obtain, low sulphur in their iron. Practically all foundry grades are sold on the understanding that the sulphur is under .05% and hence no useful purpose is served by giving the sulphur range except in a very few cases where it normally runs unusually low.

COKE AND ANTHRACITE IRONS

ADRIAN.—Adrian fce., DuBois, Pa. (Adrian Fce. Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.
Sil. 1.0-4.0% Mang. .4-1.2% Phos. .4-.9%

ALICE.—Alice fce., Birmingham, Ala. (Tenn. Coal, Iron & Ry. Co.)
Hot blast, coke, sand or chill cast iron, from Ala. red & brown ores.

Fdry.	Sil. 1.0-4.0%	Mang. .1-.4%*	Phos. .71-.0%
Basic	under 1%	.1-.4	under 1%

ALICE.—Alice fce., Sharpsville, Pa. (The Youngstown Sheet & Tube Co.)
Hot blast, coke iron, from Lake Superior ores.
Usually make Bessemer only for use in their own steel works.

ALLEGHANY.—Alleghany fce., Iron Gate, Va. (Oriskany Ore & Iron Co.)
Hot blast, coke, sand cast, foundry iron, from local brown ores.
Sil. 1.0-4.0% Mang. .7-1.5% Phos. .2-.6%

ALLEGHENY.—McKeefrey fce., Leetonia, O. (McKeefrey & Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.
Sil. .7-2.0% Mang. .4-.8% Phos. .4-.7%

ANDOVER.—Andover fce., Phillipsburg, N. J. (Andover Iron Co.)
Hot blast, coke, sand cast, foundry iron, from local magnetic ore, Lake Superior ore, iron nodules and roll scale.
Sil. 1.5-4.0% Mang. .6-1.5% Phos. .6-.9%

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* Sometimes higher.

A. R. MILLS.—(2 stacks), Allentown, Pa. (Allentown Rolling Mills Co.)
Hot blast, anthracite and coke iron, from local hematites and N. J. & N. Y. magnetites.

ASHLAND.—Ashland fces. (2 stacks), Ashland, Ky. (Ashland Iron & Min. Co.)
Hot blast, raw coal & coke, sand cast iron, from local brown and Lake Superior ores.

High Sil. Fdry.	Sil. 5.0–12.0%	Mang. .5–.8%	Phos. .5–9%
Bess. Ferro Sil.	9.0–14.0%	.5–.8%	under .1%

AURORA.—Aurora fce., Columbia, Pa. (Susquehanna Iron Co.)
Hot blast, anthracite & coke, forge & foundry iron, from native & Lake Superior ores.
Not in operation, March, 1910.

BATTELLE.—Battelle fce., Battelle, Ala. (Lookout Mt. Iron Co.)
Hot blast, coke, sand cast, foundry iron, from local red hematite.
Not in operation March, 1910.

BAY VIEW.—Bayview fces. (2 stacks), Milwaukee, Wisc. (Illinois Steel Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Mall. Bes.	Sil. 1.0–3.0%	Phos. under .20%	Mang. .50–1.0%
Fdry.	1.0–3.0%	over .50%	.50–1.0%

BELFONT.—Belfont fce., Ironton, O. (Belfont Iron Works Co.)
Hot blast, coke, fdry. iron, sand cast, from Lake Sup. & Native ores.
Sil. 1.50–2.50% Phos. .40–.70% Mang. .50–.90%

BELLEFONTE.—Bellefonte fce., Bellefonte, Pa. (Bellefonte Furnace Co.)
Hot blast, coke, sand cast, foundry iron, from Native & Lake Sup. ores.
Sil. 1.75–4.0% Phos. .5–.7% Mang. .5–.7%

BELMONT.—Belmont fce., Wheeling, W. Va. (Wheeling Iron & Steel Co.)
Hot blast, coke, sand cast, from Lake Superior ores.
Make only iron for their own steel plant.

BESSEMER.—Bessemer fces. (5 stacks), Bessemer, Ala. (Tenn C. I. & Ry. Co.)
Same as De Bardeleben, which see.

BESSIE.—Bessie fce., New Straitsville, O. (Bessie Ferro Silicon Co.)
Hot blast, coke & raw coal, sand cast, ferro silicon, from Lake Superior low phos. ore.
Sil. 8.0–14.0% Phos. under .10% Mang. under 1.0%

BIG STONE GAP.—Union fce. No. 1, Big Stone Gap, Va. (Union Iron & Steel Co.)
Hot blast, coke, sand cast, fdry iron, from local fossil. brown ores.
Sil. usually high Phos. .40–.80% Mang. .40–1.0%

BIRD.—Bird fce., Culbertson, O. (The Bird Iron Co.)
Hot blast, coke, sand cast, fdry iron, from Lake Superior & native ores.
Not in operation March, 1910.

BOYD.—Ashland fces. (2 stacks), Ashland, Ky. (Ashland I. & Min. Co., Inc.)
Hot blast, raw coal & coke, sand cast. fdry iron, from Bath Co. & Lake Superior ores.
Sil. 1.50–3.0% Phos. .40–.90% Mang. .50–.80%

BRIER HILL.—Grace fce, No. 2, Youngstown, O. (The Brier Hill I. & C. Co.)
Hot blast coke basic & Bessemer iron, from Lake Superior ores.

BRISTOL.—Bristol fce., Bristol, Tenn. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, from local brown ores.

Fdry.	Sil. 2.0–2.75%	Phos. abt. .50%	Mang. abt. .75%
Basic (chill cast)	low	abt. .60%	1.0–1.50%

BROOKE.—Brooke fces., (2 stacks), Birdsboro, Pa. (E. & G. Brooke Co.)
Hot blast, anthracite and coke, from Lake Superior, Newfoundland and Magnetic ores.

BUCKEYE.—Columbus fces., (2 stacks), Columbus, O. (The Columbus I. & S. Co.)
Hot blast, coke, chill mold iron, from Lake Superior ores.

Fdry.	Sil. 1.0–3.0%	Phos. .40–.60%	Mang. .60–.80%*
Mal. Bes.	.50–2.50	under .20	.60–1.0†
Basic	under 1.0	" .20	.80–1.0
Stand. Bes.	1.0–2.0	" .10	

BUENA VISTA.—Buena Vista fce., Buena Vista, Va. (Oriskany Ore & Iron Co.)
Hot blast, coke, chill, and sand cast iron, from Oriskany brown hematite.

Fdry.	Sil. 1.0–4.0%	Phos. .2–1.0%	Mang. .6–1.5%
Basic	under 1.0	.2– .5	.6–1.5
Spec. Car Wheel	1.0–1.50	.2– .5	.6–1.5

* Sometimes higher. † Higher or lower if desired.

BUFFALO.—Buffalo Union fce., (3 stacks), Buffalo, N. Y. (The Buffalo U. F. Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Fdry.	Sil. 1.50–3.25%	Phos .40–.70%	Mang. .50–1.0%
Mal.	.75–2.0	.10–.20	.40–1.0

BURDEN.—Burden fce., Troy, N. Y. (The Burden Iron Co.)
Hot blast, mixed anthracite coal and coke, occasionally coke alone. Magnetic concentrates from northern New York.
Out of operation March, 1910.

CARBON.—Carbon fce., Perryville, Pa. (Carbon Iron & Steel Co.)
Hot blast, anthracite coal and coke foundry iron, magnetic from N. J. & Lake Champlain, Lake Superior, and foreign ores.
Sil. 1.50–3.00% Phos. .40–.90% Mang. .40–.90%

CARONDELET.—Missouri fce., So. St. Louis, Mo. (St. Louis Blast Fce. Co.)
Hot blast, coke, Missouri red and brown hematite.
Analysis refused.

CHATEAUGAY.—Standish fce., Standish, N. Y. (Northern Iron Co.)
Hot blast, coke, sand cast, foundry iron, from local magnetic ores.
Sil. 1.0–3.0% Phos. .02–.035% Mang. .15–.50%

CHATTANOOGA.—Chattanooga fce., Chattanooga, Tenn. (The Southern I. & S. Co.)
Hot blast, coke, sand cast, foundry iron, from Alabama red and Georgia brown hematite.
Sil. 1.50–3.50% Phos. 1.0–1.5% Mang. .6–1.0%*

CHERRY VALLEY.—Cherry Valley fce., Leetonia, O. (United I. & S. Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.
Sil. as desired Phos. .20–.60% Mang. .60–.80%

CHICKIES.—Chickies fces., (2 stacks), Chickies, Pa. (Standard Iron Min. & Furnace Co.)
Hot blast, anthracite and coke, sand cast, foundry iron, from magnetites.

CITICO.—Citico fce., Chattanooga, Tenn. (Citico Furnace Co.)
Hot blast, coke, sand cast, soft foundry, from red and brown hematites from Tennessee and Georgia.
Sil. 2.0–3.0% Phos. abt. 1.25% Mang. abt. .60%

CLAIRE.—Claire fce., Sharpsville, Pa. (Claire Furnace Co.)
Hot blast, coke, Bessemer iron only, from Lake Superior ores.

* Sometimes higher.

CLEVELAND.—Cleveland fces., (2 stacks), Cleveland, O. (Cleveland Furnace Co.)
Hot blast, coke, from Lake Superior ores.
Analysis refused.

CLIFTON.—Clifton fces., (2 stacks), Ironaton, Alabama. (Alabama Consol. C. & I. Co.)
Hot blast, coke, sand cast, foundry iron, from local brown hematite.
Sil. 1.0–6.0% Phos. .35–.70% Mang. 1.0–2.0%

CLIMAX.—Hubbard fces., (2 stacks), Hubbard, O. (The Andrews & Hitchcock I. Co.)
Hot blast, coke, sand cast, strong foundry iron, from Lake Superior ores.
Sil. 1.35–1.75% Phos. .30–.40% Mang. .50–.80%

CLINTON.—Clinton fce., Pittsburgh, Pa. (Clinton I. & S. Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.
Sil. up to 3.0% Phos. .20–.75% Mang. .50–1.0%

COLONIAL.—Colonial fces., (2 alt. stacks), Riddlesburg, Pa. (Colonial Iron Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior and native ores.
Sil. up to 4.0% Phos. .40–.60% Mang. .50–.80%

COVINGTON.—Covington fce., Covington, Va. (Low Moor Iron Co. of Va.)
Hot blast, coke, sand cast iron, from native brown hematite.

Fdry.	Sil. 1.5–3.0%	Phos. .90–1.2%	Mang. .70–1.0%
High Sil. Silvery	4.0–8.0	.90–1.2	.70–1.0

CRANBERRY.—Cranberry fce., Johnson City, Tenn. (The Cranberry Fce. Co.)
Hot blast, coke, sand cast, low phos. iron, from local magnetic ore.
Sil. 1.0–3.5% Phos. under .035% Mang. .4–.6%

CRANE.—Crane fces., (3 stacks), Catasauqua, Pa. (Empire S. & I. Co.)
Hot blast, anthracite and coke, sand cast iron, from N. J. magnetic, Pa. hematite, Lake Superior and foreign ores.

Fdry.	Sil. 1.75–3.50%	Phos. .60–.90%	Mang. .50–2.0%
Basic	under 1.0	under 1.0	.50–.80
Low Phos.	1.0–3.0	" .03	.50–3.0

CROZER.—Crozer fces., (2 stacks), Roanoke, Va. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, sand cast iron, from Va. limonite, mountain and specular ores.

Fdry.	Sil. 2.10–2.75%	Phos. .60–.80%	Mang. .60–.90%
Basic	" abt .70	" abt. .70	" abt. 1.25

CUMBERLAND.—Cumberland fce., Cumberland Fce. P. O., Tenn. (Warner Iron Co.)
Hot blast, coke, sand cast foundry, from local brown and red hematites.
Sil. 2.0–4.5% Phos. abt. 2.0% Mang. abt. .30%

DAYTON.—Dayton fces., (2 stacks), Dayton, Tenn. (The Dayton C. & I. Co. Ltd.)
Hot blast, coke, sand cast, foundry iron, from Tenn. fossil. and Georgia hematite.

DE BARDELEBEN.—Bessemer fces., (5 stacks), Bessemer, Tenn. (Tenn. C. I. & Ry. Co.)
Hot blast, coke, sand and chill cast iron, from local red and brown hem.

Fdry. & Mill	Sil. up to 3.25%	Phos. .70–1.0%	Mang. .10–.40%
Basic	up to 1.0	Up to 1.0	.10–.40

DETROIT.—Detroit fce., Detroit, Mich. (Detroit Furnace Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.

DORA.—Dora fce., Pulaski City, Va. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, sand cast foundry iron, from native limonite and mountain ores.
Sil. 1.50–3.00% Phos. .40–.80% Mang. .50–.90%

DOVER.—Dover fce., Canal Dover, O. (The Pa. Iron & Steel Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.

DUNBAR.—Dunbar fces., (2 stacks), Dunbar, Pa. (Dunbar Furnace Co.)
Hot blast, coke, sand or machine cast iron, from Lake Superior specular and soft ores.

Fdry.	Sil. 1.5–3.0%	Phos. .30–.60	Mang. .30–.60%
Malleable	1.0–2.0	under .20	.30–.80

DURHAM.—Durham fce., Riegelsville, Pa. (Durham Iron Co.)
Hot blast, anthracite and coke, sand cast iron, from Lake Superior, local hematite and New Jersey magnetite.

ELIZA.—Pittsburgh fces., (5 stacks), Pittsburgh, Pa. (Jones & Laughlin St. Co.)
Hot blast, coke, Bessemer and basic, machine cast iron, from Lake Superior ores.

ELLA.—Ella fce., West Middlesex, Pa. (Pickands, Mather & Co.)
Hot blast, coke, foundry and malleable iron, from Lake Superior ores.
On account of the large assortment of ores available, this furnace can make practically any desired composition.

EMBREEVILLE.—Embreeville fce., Embreeville, Tenn. (Embree Iron Co.)
Hot blast, coke, foundry iron, from local brown hematite.

EMPIRE.—Reading, Pa. (Empire Steel & Iron Co.)
Hot blast, anthracite and coke, foundry iron, from Lake Superior, Porman and magnetic ores.
Sil. 2.0–3.0% Phos. 1.25–2.50% Mang. .50–1.0%

EMPORIUM.—Emporium fce., Emporium, Pa. (Emporium Iron Co.)
Hot blast, coke, foundry iron, from brown hematite.
Sil. as desired Phos. abt. .80% Mang. abt. .60%

ENSLEY.—Ensley fces., (6 stacks), Ensley, Alabama. (Tenn. C. I. & Ry. Co.)
Hot blast, coke, machine cast iron, from red and brown hematite.

Basic	Sil. up to 1.0%	Phos. .70–1.0%	Mang. .10–.40%*
Fdry. & Mill	up to 2.50	.70–1.0	.10–.40*

ESSEX.—Northern fce., Port Henry, N. Y. (Northern Iron Co.)
Hot blast, coke, foundry iron, from local magnetic ores.
Sil. 1.0–2.50% Phos. .40–.90% Mang. .10–.40%

ETOWAH.—Etowah fces., (2 stacks), Gadsden, Ala. (Ala. Consol.)
Hot blast, coke, foundry iron, from local red and brown hematite.
Sil. 1.0–6.0% Phos. .70–1.20% Mang. .40–.80%

EUREKA.—Same as OXMOOR, which see.

EVERETT.—Earlston fce., Earleston, Pa. (Jos. E. Thropp.)
Hot blast, coke, foundry iron, from Lake Superior and local brown ores.
Sil. 1.50–3.50% Phos. .40–70% Mang. .50–.90%

FANNIE.—Fannie fce., West Middlesex, Pa. (United Iron & Steel Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. as desired. Phos. .20–.60% Mang. .60–.80%

FEDERAL.—Federal fces., (2 stacks), S. Chicago, Ill. (Federal Furnace Co.)
Hot blast, coke, mal. and foundry iron, from Lake Superior ore.
Sil. as desired. Phos. as desired. Mang. as desired.

FLORENCE.—Philadelphia fce., Florence, Ala. (Sloss-Sheffield S. & I. Co.)
Hot blast, coke, sand cast, foundry iron, from Ala. brown hematite.
Sil. as desired. Phos. .80–1.25% Mang. .40–.80%

* Sometimes higher.

FORT PITT.—Cherry Valley fce., Leetonia, O. (United I. & S. Co.)
Hot blast, coke, spec. car wheel iron, from Lake Superior ore.
Sil. as desired. Phos. .20–.80% Mang. .60–.80%

FRANKLIN.—Franklin fce., Franklin Springs, N. Y. (Franklin Iron Mfg. Co.)
Hot blast, coke, foundry iron, from fossil. red hematite from Clinton, N.Y.
Not in operation March, 1910.
Sil. 2.25–3.0% Phos. 1.25–1.50% Mang. .25–.40%

GEM.—Same as SHENANDOAH, which see.

GENESEE.—Genesee fce., Charlotte, N. Y. (Genesee Furnace Co.)
Hot blast, coke, from Lake Superior ore.
Not in operation March, 1910.

GIRARD.—Mattie fce Girard, O. (Girard Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior ore.
Sil. 1.50–3.0% Phos. .40–.70% Mang. .50–.80%

GLOBE.—Globe fce., Jackson, O. (Globe Iron Co.)
Hot blast, raw coal and coke, sand cast, high silicon silvery iron, from native ores.
Sil. 4.0–12.0% Phos. .40–.80% Mang. .40–.80%

GRAFTON.—McKeefrey fce., Leetonia, O. (McKeefrey & Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 2.0–2.50% Phos. .40–.70% Mang. .40–.80%

GRAHAM.—Graham fce., Graham, Va. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, foundry and basic iron, from Lake Superior and native brown hematite.

HAMILTON.—Hamilton fce., Hanging Rock, O. (The Hanging Rock Iron Co.)
Hot blast, coke, sand cast iron, from native block and limestone and Lake Superior ores.

Fdry.	Sil. as desired.	Phos. .3–.4%	Mang. .5–.7%
Mall.	as desired	under .20	

HECTOR.—Clinton fce., Pittsburgh, Pa. (Clinton Iron & St. Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. up to 3.50% Phos. .50–.75% Mang. up to 1.0%

HELEN.—Helen fce., Clarksville, Tenn. (Red River Furnace Co.)
Hot blast, coke, sand cast soft, fluid foundry iron, from local brown hematite.
Sil. 2.0–3.0% Phos. ab. 1.25% Mang. .40–.60%

HENRY CLAY.—Henry Clay fces., (2 stacks), Reading, Pa. (Empire Steel & Iron Co.)
Hot blast, anthracite coal and coke, foundry and forge iron, from local hematite and magnetite.
Fdry. Sil. 1.50–4.50% Phos. 2.50–3.50%

HILLMAN.—Grand Rivers fces., (2 stacks), Grand Rivers, Ky. (Hillman Land & Iron Co.)
Hot blast, coke, foundry and forge sand cast iron, from local brown hematite.
Not in operation March, 1910.

HUBBARD.—Hubbard fces., (2 stacks), Hubbard, O. (The Andrews & Hitchcock Iron Co.)
Hot blast, coke, malleable iron, from Lake Superior ore.
Sil. 1.0–2.0% Phos. under .20% Mang. under .80%

HUBBARD SCOTCH.—Hubbard fces., (2 stacks), Hubbard, O. (The Andrews & Hitchcock Iron Co.)
Hot blast, coke, soft foundry iron, from Lake Superior ores.
Sil. up to 3.00% Phos. .59–.65% Mang. about .60%

HUDSON.—Secausus fce., Secausus, N. J. (Hudson Iron Co.)
Hot blast, anthracite coal & coke, foundry iron, from N. Y. magnetite, N. J. limonite and Lake Superior ores.
Sil. up to 3–4% Phos. .60–.95% Mang. up to .50%

IMPERIAL.—Shelby fce., No. 1, Shelby, Ala. (Shelby Iron Co.)
Hot blast, coke, iron from local brown hematite.
Not in operation March, 1910.

INLAND.—Inland fce., Indiana Harbor, Ind. (Inland Steel Co.)
Hot blast, coke, basic iron, from Lake Superior ores.

IRONATON.—Clifton fces., (2 stacks), Ironaton, Ala. (Alabama Consol. C. & I. Co.)
Hot blast, coke, foundry iron, sand cast, from local brown ore.
Sil. 1.0–6.0% Phos. .70–.90% Mang. .70–1.0%

IROQUOIS.—Iroquois fces., (2 stacks), S. Chicago, Ill. (Iroquois Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 1.35–2.50% Phos. .3–.4%* Mang. .40–.70%

IVANHOE.—Ivanhoe fce., Ivanhoe, Va. (Carter Iron Co.)
Hot blast, coke, sand cast, foundry iron, from local and Lake Superior ores.
Sil. % as desired. Phos. abt. .40% Mang. abt. .70%

* Sometimes higher.

JENIFER.—Jenifer fce., Jenifer, Ala. (Jenifer Iron & Coal Co.)
Hot blast, coke, sand cast, foundry iron, from local brown hematite.
Not in operation March, 1910.

JISCO.—Jisco fce., Jackson, O. (Jackson Iron & Steel Co.)
Hot blast, coke and raw coal, high silicon iron, from native and Lake Superior ores.
Sil. 4.0–14.0%   Phos. up to .9%   Mang. up to .9%

JOSEPHINE.—Josephine fce., Josephine, Pa. (Josephine Furnace & Coke Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Fdry.	Sil. up to 4.0%	Phos. .50–.80%	Mang. under .90%
Bessemer	1.25–2.0	.085–.10	" .90

JUNIATA.—Marshall fce., Newport, Pa. (Juniata Fce. & Fdry. Co.)
Hot blast, anthracite coal and coke, sand cast, foundry iron, from local hematite and Lake Superior ores.
Sil. up to 2.0%   Phos. under 1.0%   Mang. under 1.0%

LACKAWANNA.—(12 stacks), (Lackawanna Steel Co.)
Lackawanna fces., (7 stacks), Lackawanna, N. Y.
Bird Coleman fces., (2 stacks), Cornwall, Pa.
Colebrook fces., (2 stacks), Lebanon, Pa.
N. Cornwall fce., Cornwall, Pa.
Hot blast, coke, Bes. and basic iron, from Lake Superior and Cornwall ores.

LADY ENSLEY.—Lady Ensley fce., Sheffield, Ala. (Sloss-Sheffield S. & I. Co.)
Hot blast, coke, sand cast, foundry iron, from local brown hematite.
Sil. as desired.   Phos. 1.0–1.50%   Mang. .50–.80%

LA FOLLETTE.—La Follette fce., La Follette, Tenn. (La Follette C., I. & Ry. Co.)
Hot blast, coke, sand cast, foundry iron, from local fossil. red and brown hematite.
Sil. up to 4.0%   Phos. 1.0–1.25%   Mang. .50–.75%

L. C. R.—Lebanon, O. (Lebanon Reduction Co.)
Coke and charcoal, low phos. pig.
Operated for experimental purposes only.

LEBANON VALLEY.—Lebanon fce., Lebanon, Pa. (Lebanon Valley Fce. Co.)
Hot blast, anthracite coal and coke, sand cast, foundry iron, principally Cornwall ore.
Sil. as desired. Phos. .3-.4% Mang. .3-.4%

LEESPORT.—Leesport fce., Leesport, Pa. (Leesport Furnace Co.)
Hot blast, anthracite coal and coke, sand cast, foundry iron, from local hematite and magnetite.
Sil. as desired. Phos. 2.0-3.0% Mang. abt. 1.00%

LEHIGH.—Lehigh fce., Allentown, Pa. (Lehigh Iron & Steel Co.)
Hot blast, anthracite and coke, sand cast, foundry and mill iron, from Lake Superior, local hematite and New Jersey magnetite.
Not in operation March, 1910.

LONE STAR.—Sam Lanham fce., Rusk, Texas. (State of Texas.)
Hot blast, coke, from local brown hematite.
Not in operation March, 1910.

LONGDALE.—Longdale fce., Longdale, Va. (The Longdale Iron Co.)
Hot blast, coke, chill cast iron, from local brown hematite.

"Basic"	Sil. under 1.0%	Phos. .90-1.0%	Mang. 1.0-1.5%
"Off Basic Sil."	1.0-1.75	.90-1.0	1.0-1.50
"Off Basic Sul."*	.25-.75	.90-1.0	1.0-1.50

LOW MOOR.—Low Moor fces., (2 alt. stacks), Lowmoor, Va. (Lowmoor I. Co. of Va.)
Hot blast, coke, sand cast iron, from local brown hematite.

Fdry.	Sil. 1.5-3.0%	Phos. .80-1.0%	Mang. .90-1.2%
High Sil. Silvery	4.0-8.0	.80-1.0	.90-1.2

MACUNGIE.—Macungie fce., Macungie, Pa. (Empire Steel & Iron Co.)
Hot blast, anthracite and coke, sand cast, foundry iron, from local hematites, Lake Superior and foreign ores.
Sil. .75-3.50% Phos. .60-.90% Mang. .50-2.0%

MALLEABLE.—Iroquois fces., (2 stacks), S. Chicago, Ill. (Iroquois Iron Co.)
Hot blast, coke, sand cast, foundry iron, from Lake Superior ores.
Sil. 1.25-2.50% Phos. under .2% Mang. .40-.70%

MANNIE.—Allens Creek fces., (2 stacks), Mannie, Tenn. (Bon Air C. & I. Co.)
Hot blast, coke, sand cast, foundry iron, from local brown hematite.
Sil. up to 8.0% Phos. abt. 2.0% Mang. .40-.65%

* Sulphur over .05%.

THE MARY.—Mary fce., Lowellville, O. (The Ohio Iron & Steel Co.)
Hot blast, coke, Bessemer only, from Lake Superior ores.

MARSHALL.—Marshall fce., Newport, Pa. (Juniata Fce. & Fdry. Co.)
Hot blast, anthracite and coke, sand cast, foundry iron, from local hematite and Lake Superior ores.
Sil. up to 3.0% Phos. under 1.0% Mang. under 1.0%

MARTIN'S FERRY.—Martin's Ferry fce., Martin's Ferry, W. Va. (Wheeling Iron & Steel Co.)
Hot blast, coke, Bessemer only, from Lake Superior ores.

MAX MEADOWS.—Max Meadows fce., Max Meadows, Va. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, sand cast iron, from Va. limonite and mountain ores.

Fdry.	Sil. 1.75–2.75%	Phos. .40–.70%	Mang. 1.0–2.0%
Basic	under 1.0	under 1.0	" abt. 1.50

MIAMI.—Hamilton, O. (Hamilton Iron & Steel Co.)
Hot blast, coke, iron, from Lake Superior ores.

Fdry.	Sil. 1.0 –3.50%	Phos. .40–.70%	Mang. .50– .80%
Mall.	.75–2.0	under .20	.60–1.0
Basic	under 1.0	" .20	as desired.

MISSOURI.—Missouri fce., S. St. Louis, Mo. (St. Louis Blast Furnace Co.)
Hot blast, coke, basic iron, from Mo. red and brown hematites.
Analysis refused.

MUSCONETCONG.—Musconetcong fce., Stanhope, N. J. (Musconetcong Iron Works.)
Hot blast, anthracite and coke, foundry iron, from New Jersey magnetic, Lake Superior, Cuban and other foreign ores.
Sil. 2.50–3.50% Phos. .60–.70% Mang. .60–.70%

NAPIER.—Napier fce., Napier, Tenn. (Napier Iron Works.)
Hot blast, coke, foundry iron, from local brown hematite.
Sil. 2.0–2.75% Phos. .75–1.50% Mang. .40–.80%

NELLIE.—Ironton, O. (The Ironton Iron Co.)
Hot blast, coke, from Lake Superior ores.

Fdry.	Sil. 1.25–3.0%	Phos. .40–.60%	Mang. .50–.80%
Mall. Bes.	1.0 –2.0	under .20	.50–.90

NELLIE.—Alice & Blanche fces., (alt. stacks), Ironton, O. (The Marting I. & S. Co.)
Hot blast, coke, sand cast iron, from Lake Superior and Kentucky ores.

Fdry.	Sil. 1.0 –3.0%	Phos. .40–.60%	Mang. .50–1.0%
Mall.	.50–3.0	under .20	.50–1.0

NIAGARA.—Niagara fce., N. Tonawanda, N. Y. (Tonawanda Iron & Steel Co.)
Hot blast, coke, foundry iron, from Lake Superior hematite.
Analysis refused.

NITTANY.—Same as BELLEFONTE, which see.

NORTON.—Ashland, Ky. (Norton Iron Works.)
Hot blast, coke, mall. and Bess. iron, from Lake Superior ores.

NORWAY.—Colonial fces., (2 alt. stacks), Riddlesburg, Pa. (Colonial Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior and native ores.
Sil. up to 4.0% Phos. .60–.90% Mang. .70–1.0%

OXFORD.—Oxford fce., Oxford, N. J. (Empire Steel & Iron Co.)
Hot blast, anthracite and coke, basic iron, from local magnetic and special ores.
Sil. under 1.0% Phos. under 1.0% Mang. .75–1.25%

OXMOOR.—Oxmoor fces., (2 stacks), Oxmoor, Ala. (Tenn. Coal, I. & Ry. Co.)
Hot blast, coke, foundry and forge, sand cast, from red and brown hematite.
Sil. up to 3.50% Phos. .70–1.0% Mang. .10–.40%*

PERRY.—Carbon fce., Perryville, Pa. (Carbon Iron & Steel Co.)
Hot blast, anthracite and coke, Bess. iron, from Lake Superior, foreign, Lake Champlain and New Jersey ores.

PAXTON.—Paxton fces., (2 stacks), Harrisburg, Pa. (Central I. & S. Co.)
Hot blast, anthracite and coke, various ores.

PEERLESS.—Iroquois fces., (2 stacks), S. Chicago, Ill. (Iroquois Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 3.0–3.5% Phos. .30–.40%* Mang. .40–.70%

PENCOST.—Bessie fce., New Straitsville, O. (Bessie Ferro-Silicon Co.)
Hot blast, coke, ferro-silicon, from Lake Superior ores.
Sil. 5.0–12.0% Phos. .30–.70% Mang. under 1.0%

PEQUEST.—Pequest fce., Buttzville, N. J. (Pequest Co.)
Hot blast, anthracite and coke, foundry iron, from N. J. magnetic and manganiferous ores.
Out of blast March, 1910.

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* Sometimes higher.

PERRY.—Perry fce., Erie, Pa. (Perry Iron Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Fdry.	Sil. 1.75–3.0%	Phos. .40–.70%	Mang. .40–.80%
Fdry.	1.00–2.00	.15–.30	.40–.80
Special	2.00–3.50	1.00–1.50	.40–.80

PIONEER.—Pioneer fces., (3 stacks), Thomas, Ala. (Republic Iron & St. Co.)
Hot blast, coke, foundry iron, from red and brown hematite.
Sil. up to 3.50%* Phos. .75–.95% Mang. .40–.80%

POKEEPSIE.—Poughkeepsie fces., (2 stacks), Poughkeepsie, N. Y. (Poughkeepsie Iron Co.)
Hot blast, anthracite and coke, from Lake Superior, local brown hematite and Port Henry magnetite ores.
Not in operation March, 1910.

POUGHKEEPSIE.—Poughkeepsie fces., (2 stacks), Poughkeepsie, N. Y. (Poughkeepsie Iron Co.)
Not in operation March, 1910. (See POKEEPSIE.)

PRINCESS.—Princess fce., Glen Wilton, Va. (Princess Furnace Co.)
Hot blast, coke, foundry iron, from local limonite.
Sil. up to 3. or 4.% Phos. .60–.80% Mang. up to 1.0%

PULASKI.—Pulaski fce., Pulaski, City, Va. (Pulaski Iron Co.)
Hot blast, coke, foundry iron, from local brown ores.
Sil. 2.0–3.50% Phos. .50–.80% Mang. .40—.70%

PUNXY.—Punxy fce., Punxsutawney, Pa. (Punxsutawney Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior hematite.
Sil. 1.0–4.0% Phos. .40–.60% Mang. .45–1.60%

RADFORD.—Radford Crane fce., Radford, Va. (Va. Iron, Coal & Coke Co.)
Hot blast, coke, foundry iron, from Va. limonite and mountain ores.
Sil. 1.5–2.75% Phos. abt. 1.00% Mang. abt. 1.25%

REBECCA.—Rebecca fces. (2 stacks), Kittanning, Pa. (Kittanning I. & S. Mfg. Co.)
Hot blast, coke, chill cast iron, from Lake Superior ores.

Fdry.	Sil. up to 3.0%	Phos. .40–.80%	Mang. under 1.0%
Basic	under 1.0	under .50	" 1.0
Mall.	1.0–1.50	" .20	" 1.0

* Sometimes up to 8.00%.

RED RIVER.—Helen fce., Clarksville, Tenn. (Red River Furnace Co.)
Hot blast, coke, from local brown hematite.

Fdry.	Sil. 2.0– 3.0%	Phos. abt. .80%	Mang. abt. .65%
Scotch	3.5– 5.5	" .80	" .60
High Silicon	8.0–12.0	" .80	" .40

RISING FAWN.—Rising Fawn fce., Rising Fawn, Ga. (Southern I. & S. Co.)
Hot blast, coke, iron from red and brown hematites.
Not in operation March, 1910.

ROANOKE.—West End fce., Roanoke, Va. (West End Furnace Co.)
Hot blast, coke, foundry iron, from Va. brown hematite.
Sil. as desired. Phos. .75–1.0% Mang. .50–1.0%

ROBESONIA.—Robesonia fce., Robesonia, Pa. (Robesonia Iron Co. Ltd.)
Hot blast, anthracite and coke, foundry iron, from Cornwall ore.
Sil. 2.0–3.50% Phos. under .04% Mang. abt. .10%

ROCKDALE.—Rockdale fce., Rockdale, Tenn. (Rockdale Iron Co.)
Hot blast, coke, iron from Tenn., brown hematite.

Fdry.	Sil. 2.0–2.75%	Phos. abt. 1.40%	Mang. abt. .25%
Ferro Phos.	.07–.75	17.0–22.0	.15–.25

ROCKHILL.—Rockhill fces., (2 alt. stacks), Rockhill P. O., Pa. (Rockhill Fce. Co.)
Hot blast, coke, iron from fossil. and Lake Superior ores.
Not in operation March, 1910.

ROCKWOOD.—Rockwood fces., (2 stacks), Rockwood, Tenn. (Roane Iron Co.)
Hot blast, coke, foundry iron, from red fossil. ore.
Sil. 1.75–2.75% Phos. abt. 1.40% Mang. abt. .50%

SAMPSON STRONG.—Upson fce., Cleveland, O. (Upson Nut Co.)
Hot blast, coke, foundry iron, from Lake Superior ore.
Sil. 1.5–1.8% Phos. .40–.60% Mang. .60–1.0%

SARAH.—Sarah fce., Ironton, O. (The Kelley Nail & Iron Co.)
Hot blast, coke, Bessemer iron, from Lake Superior ore.

SAXTON.—Saxton fces. (2 stacks), Saxton, Pa. (Jos. E. Thropp.)
Hot blast, coke, foundry iron, from Lake Superior and local brown ores.
Sil. 1.5–3.5% Phos. .40–.90% Mang. .50–.90%

SCOTTDALE.—Scottdale fce., Scottdale, Pa. (Scottdale Furnace Co.)
Hot blast, coke, foundry iron, from Lake Superior ore.

SENEGA.—McKeefrey fce., Leetonia, O. (McKeefrey & Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 1.0–2.0% Phos. under .20% Mang. .40–.80%

SHARPSVILLE.—Sharpsville fce., Sharpsville. Pa. (Sharpsville Fce. Co.)
Hot blast, coke, mostly Bess. iron, from Lake Superior and New York magn. ores.

SHEFFIELD.—Sheffield fces., (3 stacks), Sheffield, Ala. (Sheffield C. & I. Co.)
Hot blast, coke, foundry iron, from Alabama and Tennessee brown hematites.
Sil. as desired. Phos. abt. 1.00% Mang. abt. .50%

SHEFFIELD.—Hattie Ensley fce., Sheffield, Ala. (Sloss-Sheffield S. & I. Co.)
Hot blast, coke, foundry iron, from local brown hematite.
Sil. as desired. Phos. abt. 1.20% Mang. abt. .50%

SHENANDOAH.—Gem fce., Shenandoah, Va. (Oriskany Ore & Iron Co.)
Hot blast, coke, foundry iron, from local brown hem. and Lake Superior ores.
Sil. as desired. Phos. .40–.80% Mang. .60–1.0%

SHENANGO.—Shenango fces., (5 stacks), Sharpsville, Pa. (Shenango Fce. Co.)
Hot blast, coke, basic, chill cast iron, from Lake Superior ores.
Sil. under 1.0% Phos. under .05% Mang. .70–1.30%

SHERIDAN.—Sheridan fce., Sheridan, Pa. (Berkshire Iron Works.)
Hot blast, anthracite and coke, foundry iron, sand cast, from Cornwall local hematite.
Sil. 1.0–4.0% Phos. .40–.90% Mang. up to .75%

SILVER CREEK.—Rome fce., Rome, Ga. (Silver Creek Furnace Co.)
Hot blast, coke, sand cast, foundry iron, from red and brown hematite, local.
Sil. up to 5.0% Phos. under 1.0% Mang. up to 2.0%

SILVER SPRING.—Paxton fces., (2 stacks), Harrisburg, Pa. (Central I. & S. Co.)
Hot blast, anthracite and coke, foundry iron, from various ores.

SLOSS.—Sloss fces., (4 stacks), Birmingham, Ala. (Sloss-Sheffield S. & I. Co.)
Hot blast, coke, foundry iron, from red fossil., hard and soft and brown hematites.
Sil. as desired. Phos. abt. .75% Mang. abt. .40%

SOHO.—Soho fce., Pittsburg, Pa. (Jones & Laughlin Steel Co.)
Hot blast, coke, basic and Bes. iron, from Lake Superior ores.

SOUTH PITTSBURG.—So. Pittsburg fces., (3 stacks), So. Pittsburg. Tenn. (Tenn. Coal, Iron & R. R. Co.)
Hot blast, coke, mill and foundry, sand cast iron, from local hard red hematite, and brown hematite from Georgia.
Sil. up to 3.50%* Phos. 1.00–1.50% Mang. .50–1.50%

SPRING VALLEY.—Spring Valley fce., Spring Valley, Wisc. (Spring Valley Iron & Ore Co.)
Hot blast, coke or sometimes charcoal, sand cast iron, from brown hematite ore.

Mall.	Sil. .80–1.50%	Phos. under .20%	Mang. 1.0–1.5%
Fdry.	1.5 –3.00	" .20	1.0–1.50

STANDARD.—Standard fce., Goodrich, Tenn. (Standard Iron Co.)
Hot blast, coke, foundry iron, from local brown hematite.
Sil. 1.75–4.50% Phos. abt. .95% Mang. abt. .40%

STAR.—Star fce., Jackson, O. (Star Furnace Co.)
Hot blast, raw coal and coke, sand cast, Jackson Co. softener, from native limonite and block ores.
Sil. 5.00–12.00% Phos. .43–.80% Mang. abt. .70%

STAR & CRESCENT.—Rusk fce., Cherokee Co., Pa. (Frank A. Daniels.)
Hot blast, coke, foundry iron, from local brown hematite and black ores.
Not in operation March, 1910.

STERLING SCOTCH.—Iroquois fces., (2 stacks), So. Chicago, Ill. (Iroquois I. Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 2.50–3.0% Phos. .30–.40% Mang. .40–.70%

STEWART.—Stewart fce., Sharon, Pa. (Stewart Iron Co., Ltd.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Bess.	Sil. 1.0–2.50%	Phos. .09–.10%	Mang. .60–.80%
Low Phos.	1.0–2.50	under .04	.20–.40

STRUTHERS.—Aurora fce., Struthers, O. (The Struthers Fce. Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Basic	Sil. under 1.00%	Phos. under .25%	Mang. .60–1.2%
Malleable	1.00–1.50	" .20	abt. 1.0

* Sometimes higher.

SUSQUEHANNA.—(2 stacks), Buffalo, N. Y. (Buffalo & Susquehanna Iron Co.)
Hot blast, coke, from Lake Superior ores.
Analysis refused.

SWEDE.—Swede fces., (2 stacks), Swedeland, Pa. (Richard Heckscher & Sons Co.)
Hot blast, coke, sand cast iron, from Lake Superior and high grade foreign ores.

Fdry.	Sil. up to 3.25%	Phos. up to .80%	Mang. up to .80%
Basic	up to 1.00	up to 1.0	up to 1.25
Bess.	1.0–2.0	up to .10	up to 2.0
Low Phos.	1.0–2.50	up to .035	up to 4.50
Spec. High Mang.	1.0–1.50	up to .80	over 1.50

SYDNEY.—Mayville fces., (2 stacks), Mayville, Wisc. (Northwestern Iron Co.)
Hot blast, coke, foundry iron, from Lake Superior and local ores.
Sil. 1.40–2.50% Phos. .60–.80% Mang. .50–1.0%

TALLADEGA.—Talladega fce., Talladega, Ala. (Northern Ala. C., I., & RR. Co.)
Hot blast, coke, foundry iron, from native brown ore.
Not in operation March, 1910.

TEMPLE.—Temple fce., Reading, Pa. (Temple Iron Co.)
Hot blast, anthracite and coke, foundry iron, from Lake Superior, local hematite, N. J. magnetic and foreign ores.
Sil. 1.75–3.50% Phos. .60–.80% Mang. .40–.80%

THOMAS.—Thomas fce., Milwaukee, Wisc. (Thomas Furnace Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Mal. Bess.	Sil. 1.00–2.00%	Phos. .10–.20%	Mang. .40–1.25%
Fdry.	As desired.	.15–.60	.50–1.25

THOMAS.—(9 stacks). (The Thomas Iron Co.)
Hokendauqua fces., (4 stacks), Hokendauqua, Pa.
Keystone fce., (1 stack), Island Park, Pa.
Lock Ridge fces., (2 stacks), Alburtis, Pa.
Saucon fces., (2 stacks), Hellertown, Pa.
Hot blast, anthracite and coke, sand and chill cast iron, from local brown hematite, N. J. magnetic and foreign ores.

Fdry.	Sil. as desired	Phos. .60–.90%	Mang. abt. .50%
Basic	under 1.0%	under 1.0	variable

TOLEDO.—Toledo fces., (2 stacks), Toledo, O. (Toledo Furnace Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Mal.	Sil. 1.00–2.00%	Phos. under .20%	Mang. .60–1.25%
Basic	under 1.0	" .20	.60–1.25
Fdry.	1.25–2.25	.50–.60	.60–1.25
Scotch	2.25–3.00	.50–.60	.60–1.25

TONAWANDA SCOTCH.—Niagara fces., (2 stacks), N. Tonawanda, N. Y. (Tonawanda Iron & Steel Co.)
Hot blast, coke, foundry iron, from Lake Superior hematite.
Analysis refused.

TOP MILL.—Top fce., Wheeling, W. Va. (Wheeling Iron & Steel Co.)
Hot blast, coke, Bess. iron, from Lake Superior ores.

TOPTON.—Topton fce., Topton, Pa. (Empire Steel & Iron Co.)
Hot blast, anthracite and coke, foundry iron, from Lake Superior, native hematite and magnetite ores..
Sil. .75–3.50% Phos. .60–.90% Mang. .50–2.00%

TRUSSVILLE.—Trussville fce., Trussville, Ala. (Southern I. & S. Co.)
Hot blast, coke, sand cast, foundry iron, from Alabama red and Georgia brown hematites.
Sil. up to 3.50% Phos. .90–1.20% Mang. .50–1.50%

TUSCALOOSA.—Central fce., Holt, Ala. (Central Iron & Coal Co.)
Hot blast, coke, sand cast, foundry iron from red and brown hematites.
Sil. 1.25–2.75% Phos. .80–1.0% Mang. .50–.90%

TUSCARAWAS.—Dover fce., Canal Dover, O. (The Penn. I. & C. Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.

UNION.—Buffalo Union fces., (3 stacks), Buffalo, N. Y. (Buffalo Union Furnace Co.)
Hot blast, coke, foundry scotch iron, from Lake Superior ores.
Sil. 1.75–2.50% Phos 1.20–1.50% Mang. .50–1.0%

UPSON SCOTCH.—Upson fce., Cleveland, O. (Upson Nut Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.
Sil. 2.0–3.0% Phos. .40–.60% Mang. .60–.90%

VANDERBILT.—Vanderbilt fces., (2 stacks), Birmingham, Ala. (Birmingham C. & I. Co.)
Hot blast, coke, foundry iron, from local hematites.
Sil. up to 4.00% Phos. under 1.00% Mang. .40–1.00%

VESTA.—Vesta fce., Watts, Pa. (Susquehanna Iron Co.)
Hot blast, anthracite and coke, foundry iron, from local hematites and magnetites.
Not in operation March, 1910.

VICTORIA.—Victoria fce., Goshen, Va. (The Goshen Iron Co.)
Hot blast, coke, foundry and forge iron, from brown hematite from Rich Patch mines.
Sil. as desired. Phos. .40–.80% Mang. 1.0–1.50%

VIKING.—Same as CARBON, which see.

WARNER.—Cumberland fce., Dickson Co., Tenn. (Warner Iron Co.)
Hot blast, coke, foundry iron, from local red and brown hematite.
Sil. 2.0–2.75% Phos. abt. 1.60% Mang. abt. .40%

WARWICK.—Warwick fces., (3 stacks), Pottstown, Pa. (Warwick I. & S. Co.)
Hot blast, coke, machine cast foundry iron, from Lake Superior, N. Y., New Jersey, and foreign ores.
Sil. 1.0–3.0% Phos. .40–.80% Mang. .40–.80%

WATTS.—Watts fces., (2 stacks), Middlesborough, Ky. (Va. Coal & Coke Co.)
Hot blast, coke, foundry iron, from native ores.
Sil. 1.50–2.75% Phos. abt. .45% Mang. abt. .20%

WELLSTON.—Wellston fces., (2 stacks), Wellston, O. (Wellston S. & I. Co.)
Hot blast, coke, sand cast iron, from Lake Superior ores.

Str. fdry.	Sil. 1.50–1.75%	Phos. .18–.20%	Mang.	.60–.90%
Mall.	.60–2.00	" under .20		.40–1.00

WHARTON.—Wharton fces., (3 stacks), Wharton, N. J. (Joseph Wharton.)
Hot blast, coke, occas. some anthracite, from N. J. mag., N. Y. and Lake Superior hematites.

WICKWIRE.—Wickwire fce., Buffalo, N. Y. (Wickwire Steel Co.)
Hot blast, coke, basic iron, from Lake Superior ores.

WILLIAMSON.—Williamson fce., Birmingham, Ala. (Williamson Iron Co.)
Hot blast, coke, iron from red fossil, and brown hematite.

WOODSTOCK.—Woodstock fces., (2 stacks), Anniston, Ala. (Woodstock I. Wks. Inc.)
Hot blast, coke, foundry iron, from local brown hematite.
Sil. 1.50–5.00% Phos. abt. 1.15% Mang. .80–1.25%

WOODWARD.—Woodward fce., Woodward, Ala. (Woodward Iron Co.)
Hot blast, coke, foundry iron, from local red fossil. ores.
Sil. 1.0–3.0% Phos. abt. .80% Mang. abt. .30%

ZENITH.—Zenith fce., W. Duluth, Minn. (Zenith Furnace Co.)
Hot blast, coke, iron, from Lake Superior ores.

Bess.	Sil. 1.00–2.00%	Phos. .08–.10%	Mang. under 1.0%
Mall.	1.00–2.00	under .2	.80–1.20
Fdry.	1.50–5.00	" .20	over .60

ZUG.—Detroit, Mich. (Detroit Iron & Steel Co.)
Hot blast, coke, foundry iron, from Lake Superior ores.

CHARCOAL IRONS

AETNA.—Aetna, Ala. (J. J. Gray.)
Hot or cold blast, charcoal, car wheel iron, from local brown hematite.
Not in operation March, 1910.

ALAMO.—Quinn fce., Gadsden, Ala. (Quinn Furnace Co.)
Hot blast, charcoal, foundry iron, from local red and brown hematite.
Not in operation March, 1910.

ANCHOR.—Oak Hill, O. (Jefferson Iron Co.)
Warm blast, charcoal, strong foundry iron, from native limestone and block ores.
Sil. abt. 2.26% Phos. abt. .87% Mang. abt. .51%

ANTRIM.—Antrim fce., Mancelona, Mich. (Superior Charcoal Iron Co.)
Hot blast, charcoal, foundry iron, from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

BERKSHIRE.—Cheshire fce., Cheshire, Mass. (Berkshire Iron Works.)
Warm blast, charcoal, foundry iron, from local red and brown hematite.

BERLIN.—Glen Iron fce., Glen Iron, Pa. (John T. Church.)
Cold blast, charcoal, iron from local fossil. and hematite.
Sil. 1.0–1.5% Phos. .50–.65% Mang. .40–.60%

BLOOM.—Bloom Switch, O. (The Clare Iron Co.)
Hot blast, charcoal, foundry iron, from local hematite.
Not in operation March, 1910.

BLUE RIDGE.—Tallapoosa fce., Tallapoosa, Tenn. (Southern Car Wheel Iron Co.)
Cold and warm blast, charcoal, iron from brown hematite.
Phos. .18–1.50% Mang. up to 2.0%

BUCKHORN.—Olive fce., Lawrence Co., O. (McGugin Iron & Coal Co.)
Hot or cold blasts, charcoal iron, from native limestone ore.
Not in operation March, 1910.

CADILLAC.—Cadillac fce., Cadillac, Mich. (Mitchell-Diggins Iron Co.)
Hot blast, charcoal iron, from Lake Superior ores.
Sil. up to 2.50% Phos. .16–.20% Mang. up to 1.0%

CENTER.—Superior P. O., O. (The Superior Portland Cement Co.)
Charcoal iron, from native limestone.
Not in operation March, 1910.

CHAMPION.—Manistique, Mich. (Superior Charcoal Iron Co.)
Warm blast, charcoal, foundry iron from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

CHEROKEE.—Cherokee fce., Cedartown, Ga. (Alabama & Georgia Iron Co.)
Hot blast, charcoal, sand cast, strong foundry iron, from brown hematite.
Sil. up to 2.50% Phos. .35–.70% Mang. .30–1.60%

CHOCOLAY.—Chocolay fce., Chocolay, Mich. (Lake Superior Iron & Chemical Co.)
Warm blast, charcoal iron, from Lake Superior ores.

Fdry.	Sil. up to 2.0% & over	Phos. .17–.22%	Mang. up to .65% & over
Car Wheel	.05–2.0 "	.17–.22	.30–.65 "
Mall.		.17–.22	.30–.65 "

COPACKE.—Copacke Iron Works, N. Y. (Copacke Iron Works.)
Cold and warm blast, charcoal iron, from N. Y. ores.
Not in operation March, 1910.

DOVER.—Bear Spring fce., Stewart Co., Tenn. (Dover Iron Co.)
Cold blast, charcoal, foundry iron, from local brown hematite.
Sil. .40–2.0% Phos. abt. .40% Mang. abt. .25%

ELK RAPIDS.—Elk Rapids, Mich. (Superior Charcoal Iron Co.)
Hot blast, charcoal, pig for car wheels and mall., from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .36–.70%

EXCELSIOR.—Carp fce., Marquette, Mich. (Superior Charcoal Iron Co.)
Warm blast, charcoal iron, from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

GERTRUDE.—Maysville fces., (2 stacks), Maysville, Wisc. (Northwest Iron Co.)
Hot blast, charcoal, foundry iron, from Lake Superior and local ores.
Sil. 2.50% and over Phos. .60–.80% Mang. .50–1.00%

GLEN IRON.—Glen Iron fce., Glen Iron, Pa. (John T. Church.)
Cold blast, charcoal iron, from local fossil. and hematite.
Sil. up to 1.00% Phos. .70–1.25% Mang. .60–1.50%

HECLA.—Hecla fce., Milesburg, Pa. (The McCoy-Linn Iron Co.)
Cold blast, charcoal, foundry iron, from Nittany Valley hematite.
Sil. .65–1.25% Phos. abt. .30% Mang. .15–.25%

HECLA.—Hecla fce., Ironton, O. (Hecla Iron & Mining Co.)
Cold or warm blast, charcoal, foundry iron, from local ore.

HEMATITE.—Center fce., Center, Ky. (White, Dixon & Co.)
Cold blast, charcoal, foundry iron, from local hematite.
Sil. .50–1.40% Phos. .25–.39% Mang. .20–.25%

HINKLE.—Ashland fce., Ashland, Wisc. (Lake Superior Iron & Chemical Co.)
Warm blast, charcoal iron, from Lake Superior ores.
Sil. up to 3.00% Phos. .10–.18% Mang. to .70% & over

JEFFERSON.—Jefferson fce., Jefferson, Tex. (Jefferson Iron Co.)
Hot blast, charcoal iron, from local brown hematite.
Not in operation March, 1910.

LIBERTY 1812.—Liberty fce., Shenandoah, Va. (Shenandoah I. & C. Co., Va.)
Warm blast, charcoal iron, from brown hematite.

MARQUETTE.—Pioneer fce., Marquette, Mich. (Superior Charcoal Iron Co.)
Hot blast, charcoal, foundry iron, from Lake Superior ore.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

MICHIGAN.—Newberry fce., Newberry, Mich. (Superior Charcoal Iron Co.)
Warm blast, charcoal iron, from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

MUIRKIRK.—Muirkirk fce., Muirkirk, Md. (Charles E. Coffin.)
Warm blast, charcoal iron, from local carbonate ores.
Sil. .70–2.50% Phos. .25–.30% Mang. .80–2.50%

OLIVE.—Olive fce., Lawrence Co., O. (The McGugin I. & C. Co.)
Hot or cold blast, charcoal iron, from native limestone ores.

PINE LAKE.—Boyne City fce., Boyne City, Mich. (Superior Charcoal Iron Co.)
Hot blast, charcoal iron, from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

PIONEER.—Pioneer fce., Gladstone, Mich. (Superior Charcoal Iron Co.)
Warm blast, charcoal iron, from Lake Superior ores.
Sil. up to 2.62% Phos. .15–.22% Mang. .30–.70%

REED ISLAND.—Reed Island fce., Reed Island, Va. (Va. Iron, C. & C. Co.)
Cold blast, charcoal iron, from local limonite.

RICHMOND.—Richmond fce., Berkshire Co., Mass. (Richmond Iron Works.)
Warm blast, charcoal iron, from local brown hematite.
Sil. up to 2.00% Phos. .28–.35% Mang. up to .44%

ROCK RUN—Rock Run fce., Rock Run, Ala. (The Bass Foundry & Machine Co.)
Warm blast, charcoal iron for chill rolls, car wheels, strong castings, from local brown hematite.
Sil. .30–2.25% Phos. .30–.50% Mang. .40–1.00%

ROME.—Rome fce., Rome, Ga. (Silver Creek Furnace Co.)
Warm blast, charcoal iron, from local red and brown hematites.
Sil. 1.75–2.25% Phos. .35–.60% Mang. .50–.80%

ROUND MOUNTAIN.—Round Mt. fce., Round Mt., Ala. (Round Mountain Iron & Wood Alc. Co.)
Cold blast, charcoal iron, from local red hematite.
Not in operation March, 1910.

SALISBURY.—Canaan fces., East Canaan, Conn. (2 stacks). (Barnum Richardson Co.)
Warm blast, charcoal iron, from Salisbury brown hematite, sand cast.
Sil. 1.32–1.92% Phos. abt. .30% Mang. .50–1.0%

SALISBURY CHATHAM.—Chatham fce., Chatham, N. Y. (Union Iron & St. Co.)
Charcoal iron.

SHELBY.—Shelby fce., Shelby, Ala. (Shelby Iron Co.)
Warm blast, charcoal iron, from local brown hematite.
Sil. .15–2.25% Phos. .30–.50% Mang. .50–.80%

SLIGO.—Sligo fce., Sligo, Mo. (Sligo Furnace Co.)
Hot blast, charcoal iron, from local blue specular and red ore.

SPRING LAKE.—Fruitport fce., Fruitport, Mich. (Spring Lake Iron Co.)
Hot blast, sand cast, charcoal iron, from Lake Superior ores.
Sil. up to 2.50% Phos. .16–.20% Mang. up to 1.0%.

SPRING VALLEY.—See under Coke Irons.

TASSIE BELL.—Tassie Bell fce., Rusk, Tex. (New Birm. Devel. Co.)
Hot blast, charcoal iron, from local brown hematites.
Not in operation March, 1910.

WHITE ROCK.—Smyth Co., Va. (Lobdell Car Wheel Co.)
Warm and cold blast, charcoal iron, from local brown hematite.
All used by the Company.

WYEBROOKE.—Isabella fce., Wyebrooke, Pa. (W. M. Potts.)
Cold blast, charcoal iron, from local magnetic and hematites and foreign and Lake Superior ores.
Not in operation March, 1910.

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President Waterfall. "You have heard the presentation of a magnificent report and before I ask for discussion I want to say this paper has caused a great deal of comment at Convention Headquarters, and around the city where I have been, on the part of a number of foundrymen who had the paper in their hands. It appears to bring forth just the information the smaller foundrymen are looking for. The large foundrymen have their own chemical laboratories and can arrive at the information given in this report more readily, the small foundryman can only get it in this way or by the courtesy of a friend who has the facilities to acquire the information."

The Secretary. "I wish to state that the whole starting point of this monumental work of Dr. Porter's, was a letter

written to me by Mr. Archie M. Loudon, one of our members, and I had a talk with Dr. Porter about the idea. The letter said that the writer often wished to know what to do under the circumstance of orders for special classes of castings. I thought Dr. Porter was the best man to answer the question, and he was good enough to do it. I hope Dr. Porter will elaborate the report and publish a book upon the subject."

President Waterfall. "We would like to have those present ask Dr. Porter questions, and he will be glad to elaborate upon any point that is desired."

Mr. Putnam. "I am very sorry that the men who were to discuss this paper are not present. I was very much impressed with the paper and was in hopes it would bring out a discussion on some very interesting points. I had a definite promise from several of our members to be here to discuss certain pages of this paper and they have had the abstract in their hands for some little time which gave them ample opportunity to study the question and be prepared to have something, not only in the way of comment on the paper, but further information they expected they would offer at this meeting. I want to apologize to those who are here for these men who did not come as promised."

President Waterfall. "The next paper is by Mr. H. M. Lane, Cleveland, Ohio, on the 'Physics of Cast Iron.' "

Mr. Lane. "The paper itself is the result of many questions I have been asked for the last few years. I have not covered the subject fully, but have answered many questions, and I think a lot of points in connection with the physics of cast iron might be brought together in a way that would be interesting to foundrymen about which I do not pretend to say anything now in the paper. I will only call attention to some few facts that are not generally recognized. In this country we pay altogether too little attention to the physics

of cast iron as connected with machine practice. I have very interesting information from some foundrymen who would be perfectly willing to pay a cent or a cent and a half a pound more for their work if they could be guaranteed the strength and uniform machining quality."

Mr. Lane here gave his paper.

THE PHYSICS OF CAST IRON

By H. M. Lane, Cleveland, Ohio

The object of this paper is not to bring out unknown points in metallurgy or any particularly new discoveries, but rather to emphasize the importance of the physical changes which take place in a casting as the metal cools and the effect these have upon the output of the plant. Of course some of the physical changes are due to chemical changes which take place in the metal, as for instance, the chilling of the iron forming combined carbon and thus hardening it. The physical properties of a metal are naturally largely dependent upon its chemical composition, but the chemical composition of a metal suitable for one purpose is not that which should be chosen for a different class of castings.

Most foundries are connected with manufacturing concerns, and in fact form simply a department in such a concern, and hence the foundry is responsible for its portion of the final cost of the product; frequently an attempt to save in the foundry results in disastrous losses in the machine shop. A cheaper mixture or economy in the grade of coke may mean hard iron, and this in turn may increase the machining cost of much of the work from 25 to 50%, and even may necessitate the discarding of castings.

By selecting a proper grade of strong iron, cast-iron machine parts may be made lighter than is the usual custom and at the same time increased in strength. The illustrations accompanying this paper show distinctly the effect upon the

physical structure of the metal which accompanies a change in cross-section. Any given composition of metal has a certain thickness which is its most efficient thickness. In other words, if the castings be made thinner the metal will have a tendency to be chilled and the machine cost will rise, while if the castings be made thicker the grain of the casting becomes more and more open and the strength rapidly reduced.

The designing department of any plant should take these facts into consideration and in designing machine parts should have recourse to stiffening by means of webs or ribs rather than by increasing the mass of metal. Of course at times this construction increases the molding cost, and then the thicker construction may be cheaper.

A machine as it is sold consists of two elements, material and labor. The cost of the finished product can be kept down by reducing either or both, and there is no department connected with the manufacturing concern in which the proper selection of metal, the design of castings, and the selection of proper molding methods will give such a large return upon the investment, for as already stated, if the foundry delivers to the machine shop proper castings both as to strength and hardness, the output of the machine shop is greatly increased.

The foregoing remarks apply not only to foundries connected with manufacturing plants, but also to jobbing foundries, even though at first sight this may not seem true. It is easy to get a common rough grade of work in the jobbing trade by slashing prices, but as we travel through the country we find certain foundries that always command a higher price for their work than their neighbors, and an analysis of the methods in vogue at such plants usually shows that each casting is made the subject of a careful study, and the customer is shown how by having a certain grade of metal cast in a certain way he can save in machining cost, also the foundryman talks quality and convinces the manufacturer that he delivers goods which in the long run are cheaper on

account of the fact that they keep the plant running uniformly. Foundries of this kind generally take the higher grade of work, including machine castings, typewriter parts, sewing machine work, etc. Many foundries make the mistake of bidding on work at a flat price averaging various castings in a rough way, or of having two flat prices, one for cored work and one for work without cores. With iron at the spout at a given price, there are great differences in the cost per pound of the finished casting. In gray iron foundries the product per man per day varies from a little over 100 pounds to a little over 1,000 pounds, and frequently two floors side by side will vary through wide ranges, even though the sizes of the castings are almost identical. Some cored work is far more difficult than others, and at times it requires from two to four coremakers to keep one molder going. This is noticeably true in automobile work. Foundries bidding on this class of work will find piece prices far better than flat pound prices.

What is the best analysis of iron for use in a jobbing foundry? is an inquiry that is often made. Theoretically the analysis should be changed for each change in the thickness of metal, and should also depend upon the use to which the castings are to be put. If wearing qualities are required, a certain analysis will answer, while for cheap machining the castings should be very soft and hence the composition changed to suit.

The rate of cooling in a casting naturally depends upon the cross-section of the casting and the ability of the mold to extract heat rapidly from the metal. Some mixtures are so sensitive that when cast in thin sections the edges will chill in green sand molds. Other mixtures which are suitable in small work if cast in thick sections become so open that they are entirely useless.

As cast iron cools from the temperature of molten metal there is a tendency for certain portions of the mass to freeze first, and for the other portions to segregate in the thicker parts of the castings. Phosphorus in the form of phosphide

of iron has a marked tendency to segregate, also sulphur in the form of sulphide of manganese. The carbon is probably all combined until the iron comes nearly to the point of solidifying. Of course in the case of metal very rich in carbon some of the graphite separates as kish before the metal becomes solid, but in remelted or cupola metal this rarely takes place. As soon as the metal has solidified and cooled to a dull red heat, it is past the influence of temperature on its hardness, and the only effect that uncovering the casting will have upon it will be the development of unequal cooling strains which may crack or warp the casting. The change point which occurs slightly above a dull red heat corresponds to the recalescence point in steel, and of castings show a hard skin due to slight chilling, they may be softened by packing them in annealing pots, heating slightly above this temperature, and then allowing them to cool slowly until they are past the change point, after which they may be left to cool as rapidly as desired. Light machinery castings, typewriter parts, etc., are frequently annealed in this way. The annealing also tends to relieve any casting strains, and hence saves time in the machine shop and particularly in the erecting or assembling of parts.

To illustrate the effect of thickness of a casting upon its physical properties a number of foundries have co-operated and supplied wedges and test bars to illustrate the points brought out in this paper. In order that the results from different mixtures might be uniform throughout, all of the test bars were made 1¼ inches in diameter, and of such a length that they could be broken on supports 12 inches apart. The patterns were all made at one place and distributed to the different foundries. The request was made that the test bars be cast on end in dry sand, but as most foundries are not equipped for this work the bars were cast on end in green sand, the conditions being similar to those in ordinary foundry practice in the plants where the work was done.

For mixtures which are to be used in castings not over two inches in thickness wedges were cast which were 20

inches long, two inches square at the thick end, and tapered to $\frac{1}{8}$ inch by 2 inches at the narrow end. For mixtures which were used in castings over two inches in thickness additional wedges which were 4 inches in width and tapered from 4 inches to 2 inches in thickness were cast. These wedges were all drilled near the center for samples for analysis and the analytical work was done by the Detroit Testing Laboratory, of Detroit, Michigan, to whom the writer is glad to acknowledge indebtedness.

He also makes grateful acknowledgement of the use of the testing machine of the Russell Wheel & Foundry Co., Detroit, Michigan, which was loaned by A. T. Waterfall, and to the following foundries for furnishing test bars and wedges: Root & Vandervort Engine Co., of East Moline, Illinois, Mr. Becker of this company having been very kind in assisting in the work; to J. A. Kittilsen, superintendent of the Moline Scale Co., East Moline, Illinois, who also furnished wedges and test bars representing the general line of castings turned out by that firm at the time; to J. A. Murphy, foundry superintendent of the Hooven Owens Rentschler Co., Hamilton, Ohio, who supplied test bars and wedges representing two brands of iron; to Mr. Shennan, foundry superintendent of the Bethlehem Steel Co., who supplied wedges and bars representing two brands of iron used by that firm, and also a piece cut from the center of a 16-inch square riser on a large casting; to J. J. Wilson, foundry superintendent of the General Motors Co., Detroit, who supplied samples of three grades of iron used in automobile castings; to Fred Blundell, foundry superintendent of the Taylor-Boggis Foundry Co., Cleveland, Ohio, who supplied samples of two grades of iron commonly used at their foundry.

Samples were promised by a number of other firms, but labor difficulties, sickness and rush of work, delay in shipment of patterns, and other factors, prevented carrying out the plans in a number of cases. The mass of metal handled in the shape of test bars and wedges weighed over a ton. J. J. Wilson, of the General Motors Co. and A. T. Waterfall, of the Russell Wheel & Foundry Co., Detroit, looked after

TABLE ILLUSTRATING PHYSICAL PROPERTIES OF CAST IRON

TEST BARS AND WEDGES FURNISHED BY DIFFERENT FIRMS

The bars marked *a* were made by the Root & Vandervort Engine Co., East Moline, Ill.; the bars marked *b* by the Moline Scale Co., at East Moline, Ill.; the bars marked *c* were cast at the Leland Falconer plant, which is the foundry department of the Cadillac division of the General Motors Co.; the bars marked *d* were cast at the foundry of the Hooven Owens Rentschler Co., Hamilton, Ohio; the bars marked *e* by the Bethlehem Steel Co., South Bethelehem, Pa., the bars marked *f* by the Taylor & Boggis Co., Cleveland, O.

Test No.	Kind of Iron	Strength in lbs.	Diameter in inches	Pounds per sq. inch	Deflection in inches	Silicon	Sulphur	Phosphorus	Manganese	Comb. Carbon	Graphitic Carbon	Remarks	Drillings Taken From
1	Machinery Iron *a*	3,600	1.266	2,850	.211	2.23	.067	.740	.77	.44	2.84		Small Wedge
2	" " *a*	3,560	1.266	2,820	.208	"	"	"	"	"	"		" "
3	" " *a*	3,720	1.256	2,880	.222	"	"	"	"	"	"		" "
4	" " *a*	2,700	1.265	2,175	.152	"	"	"	"	"	"	Slight flaw	" "
21	" " *b*	2,950	1.284	2,240	.192	2.90	.110	.729	.61	.25	3.03		" "
22	" " *b*	2,940	1.286	2,260	.176	"	"	"	"	"	"		" "
23	" " *b*	2,720	1.282	2,100	.173	"	"	"	"	"	"		" "
24	" " *b*	3,280	1.287	2,520	.202	"	"	"	"	"	"		" "
73	Soft Iron *c*	3,720	1.230	3,130	.222	2.52	.067	.531	.67	.35	2.93		" "
77	" " *c*	3,820	1.251	3,080	.218	"	"	"	"	"	"		" "
83	" " *c*	3,750	1.258	3,020	.215	"	"	"	"	"	"		" "
85	" " *c*	3,560	1.250	2,970	.196	"	"	"	"	"	"		" "
27	Cast Iron *d*	2,740	1.266	2,180	.140	1.64	.097	.687	.56	.50	2.80		" "
28	" " *d*	3,020	1.267	2,540	.180	"	"	"	"	"	"		" "
29	" " *d*	2,900	1.267	2,310	.183	"	"	"	"	"	"		" "
30	" " *d*	3,070	1.264	2,440	.176	"	"	"	"	"	"		" "
69	" " *e*	3,220	1.279	2,510	.189	.98	.072	.705	.55	.70	2.72	Slight flaw	Large Wedge
70	" " *e*	3,420	1.279	2,660	.196	"	"	"	"	"	"		" "
71	" " *e*	3,120	1.294	2,390	.186	"	"	"	"	"	"		" "
72	" " *e*	3,440	1.287	2,640	.203	"	"	"	"	"	"		" "

65	Cast Iron	*e*	3,300	1.280	2,560	.203	1.31	.089	.611	.67	.54	2.87		Small Wedge
66	" "	*e*	3,510	1.276	2,830	.196	"	"	"	"	"	"		" "
67	" "	*e*	3,370	1.285	2,600	.192	"	"	"	"	"	"		" "
68	" "	*e*	3,380	1.282	2,620	.196	"	"	"	"	"	"		" "
97	" "	*e*					1.23	.051	.470	.66	.35	2.95		16×16 in. riser
96	Gray Iron	*f*	3,712	1.217	3,183	.218	3.12	.127	.608	.59	trace	3.06		Large Wedge
95	Steel Iron	*f*	4,342	1.217	3,733	.250	2.19	.110	.644	.70	.58	2.71		Small Wedge
38	Semi Steel	*d*	3,740	1.257	3,010	.222	1.75	.086	.385	.76	.51	2.90		" "
39	" "	*d*	3,820	1.265	3,040	.234	"	"	"	"	"	"		" "
40	" "	*d*	3,400	1.271	2,680	.203	"	"	"	"	"	"	Small blow hole	" "
41	" "	*d*	3,485	1.261	2,780	.203	"	"	"	"	"	"	" " "	" "
5	Cylinder Iron	*a*	2,800	1.271	2,180	.203	1.82	.107	.569	.55	.66	2.73		" "
5	" "	*a*	3,000	1.264	2,380	.199	"	"	"	"	"	"		" "
7	" "	*a*	3,360	1.282	2,600	.222	"	"	"	"	"	"		" "
8	" "	*a*	3,580	1.268	2,840	.221	"	"	"	"	"	"		" "
75	" "	*c*	3,150	1.211	2,740	.221	1.65	.069	.548	.67	.52	2.70		" "
76	" "	*c*	3,280	1.231	2,750	.251	"	"	"	"	"	"		" "
78	" "	*c*	3,210	1.238	2,680	.218	"	"	"	"	"	"		" "
79	" "	*c*	3,190	1.242	2,640	.218	"	"	"	"	"	"		" "
80	" "	*c*	3,190	1.230	2,650	.203	"	"	"	"	"	"		" "
74	Ring Iron	*c*	3,440	1.217	2,960	.196	1.52	.085	1.148	.49	.36	2.89		" "
81	" "	*c*	3,540	1.246	2,910	.251	"	"	"	"	"	"		" "
82	" "	*c*	3,750	1.258	3,020	.215	"	"	"	"	"	"		" "
84	" "	*c*	3,600	1.243	2,960	.196	"	"	"	"	"	"		" "

the receipt of the specimens as they arrived in Detroit, and delivered them at the convention at the State Fair Grounds. The Berkshire Manufacturing Co., of Cleveland, Ohio, looked after the shipping of the material to Cleveland, and the photographic work was done by the writer at their plant.

To facilitate the breaking of the wedges small grooves were cast in the surface dividing each wedge into five pieces, but for breaking the heavier wedges it was found best to drill a number of half-inch holes part way through the metal, and even then some pretty heavy sledge work was required to break them. The analyses given in the accompanying table represent the analysis of the mixture and the combined and graphitic carbon, and would vary quite materially from the figure given in some kinds of castings. This is particularly true in light work such as automobile castings, piston rings, etc. In the table is also a statement as to the size of the sample from which the drillings were taken, as this will affect the combined carbon. At least one wedge in each set was chilled on one face to see what effect the chilling would have on the metal. In most cases it simply closed the grain, while in some cases a white chill showed distinctly.

The specimens as received were given arbitrary numbers, so that they could be identified after analysis and after testing, and for this reason the numbers in the first column of the table are not consecutive, but refer simply to the experimental records.

The second column of the table is headed "Kind of Iron," and under this caption is given the name of the metal as it is commonly known in the foundries where it is used. The first specimens in the table are Nos. 1, 2, 3, and 4. This represents what is known as the regular or machinery iron of the Root & Vandervort Co. This is used for gas and gasoline engine castings and for certain automobile castings. The fracture of the small wedge unchilled is shown in Fig. 1. At the left is the fracture of the metal where it is about $\frac{5}{16}$ of an inch thick, and at the right the fracture where it is a little over $1\frac{3}{4}$ inches in thickness. This casting is soft and gray

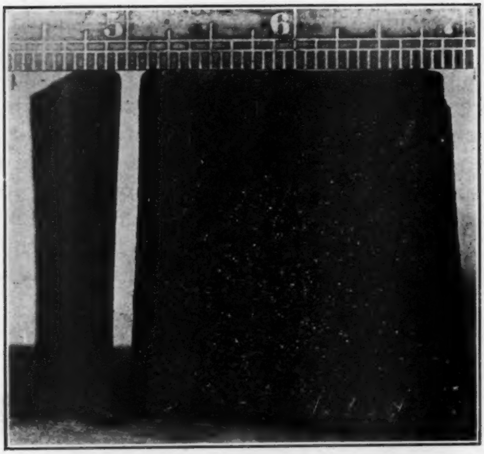

FIG. 1

throughout its entire length and even the thin casting could be machined, though it is fairly hard. The fracture of the large portion shows that this is quite an open iron, which

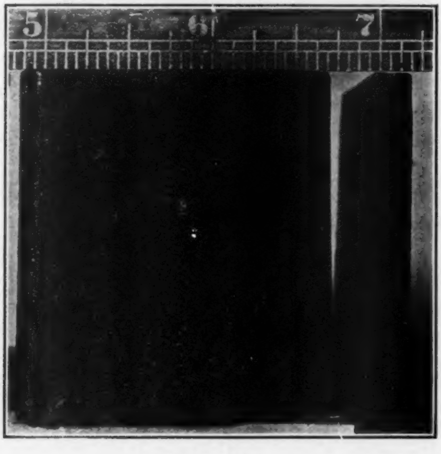

FIG. 2

would not be suitable for large work, but should be well fitted for strong castings up to an inch or an inch and a quarter in thickness. The strength is fairly high and the deflection good. In Fig. 2, a fracture of the same iron which has been chilled is shown. It will be noticed that the upper or chilled surface shows white along the edge, and that the grain of the metal has been closed for over half its depth. The chilled surface is so hard that it could not be machined, though the metal a short distance back of the chill in the body of the casting is fairly soft. The chilling has served to

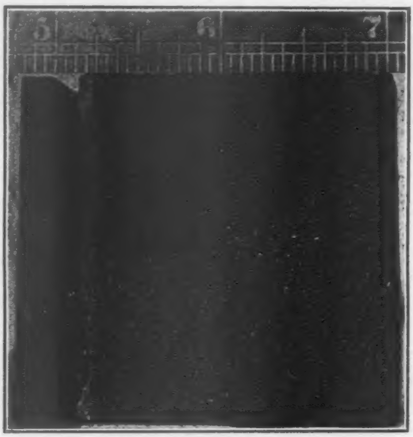

FIG. 3

make over one-half of the iron in Fig. 2, about as dense as the $5\frac{5}{16}$ inch section in Fig. 1.

For graphical comparison of the different grades of iron and their analyses the curves shown in Fig. 26 have been prepared and the information contained in the table is shown graphically by means of these curves.

The regular or machinery mixture used by the Moline Scale Co. for scale parts and general machinery castings is the second item in the table, the test bars being bars Nos.

21, 22, 23, and 24. A fracture of one of these wedges is shown in Fig. 3, where the difference between the thin end of the wedge and the thick or $1\frac{7}{8}$ inch section are plainly shown. Most of the castings for which this iron is used are less than $1\frac{1}{2}$ inches in thickness, and hence it is fairly close and strong. The placing of a chill on the side of this bar did not materially change the grain, the bar shown in Fig. 3 having had a chill placed on the top face, and it will be noticed that the metal next this face is a little closer in grain than that in the center

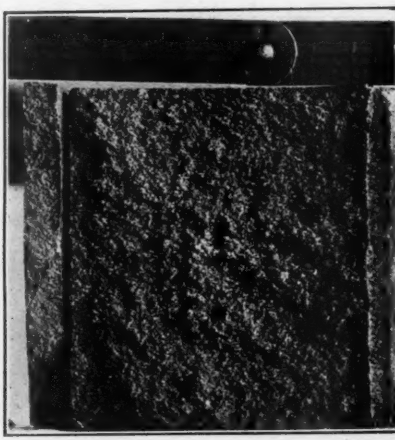

FIG. 4

of the bar. The chilling did not harden the surface so but that it could be machined with ease.

The total carbon in this and the previous mixture given is practically the same, but the silicon in the second mixture is much higher and this probably accounts for the fact that the second mixture would not chill to any appreciable extent. It will also be noticed that the second mixture is not so strong as the first, though it could undoubtedly be machined easier.

The soft iron mixture used by the Cadillac foundry of

the General Motors Co. is the third one in the table, the test bars being Nos. 73, 77, 83, and 85. A fracture of the metal is shown in Fig. 4. This metal is so open and soft that it does not take a chill, the only effect of placing a chill next the bar being to close the grain slightly. Attention is called to the character of the fracture, which shows a closely knit structure indicating considerable strength. The record of the test bars bears this out with an average strength of about 3,000 pounds per square inch for transverse tests. All three of these mixtures would be considered good machinery mixtures for light and medium work. The cupola practice or

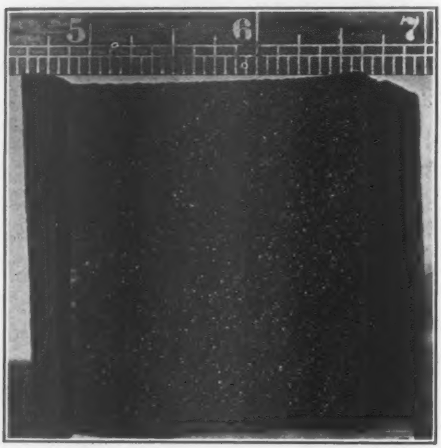

FIG. 5

melting undoubtedly plays an important part in the strength of the iron. An ample amount of coke of good quality should be used and the bed always kept at the most efficient height. The coke charge in the cupola should be weighed rather than measured, and every phase of the cupola practice carefully watched to see that the charges are so placed that the metal will be melted uniformly and come down thoroughly mixed.

A machinery mixture for slightly heavier work is the fourth one given in the table, the bars being Nos. 27, 28, 29,

and 30. This is one of the mixtures used at the Hooven Owens Rentschler Co. The fracture of one of the bars unchilled is shown in Fig. 5, while the fracture of a chilled bar is shown in Fig. 6. It will be noticed that this metal takes quite a deep chill, the surface becoming white. The chill is not sharp, however, but blends off gradually into the gray iron backing. This metal is much lower in silicon than those previously shown, the total carbon, however, is not much different from the other mixtures. The specimen shown in Fig. 5 clearly illustrates the exceedingly close grain of the

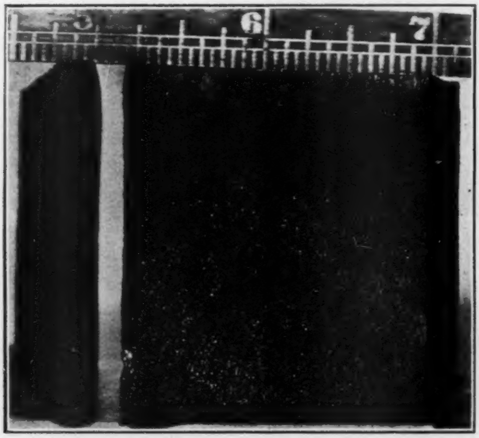

FIG. 6

small end of the bar, showing the effect of casting this metal into a thin section. The character of the fracture of both pieces shows a strong, well-knit material.

The same iron cast in one of the larger wedges is shown in Fig. 7, this wedge having been chilled on the lower face and the effect of the chill extending some distance into the metal. It will be noticed that some of the holes drilled to assist in breaking the bar ran down into the chilled metal, but no particular difficulty was encountered in drilling, and

FIG. 7

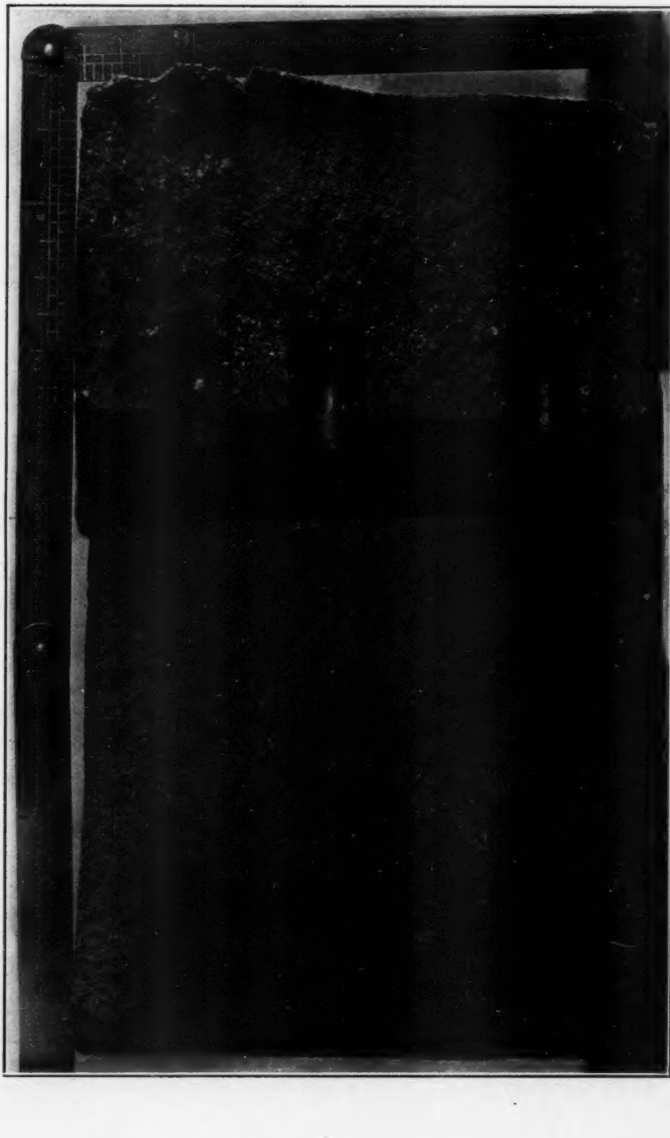

FIG. 8

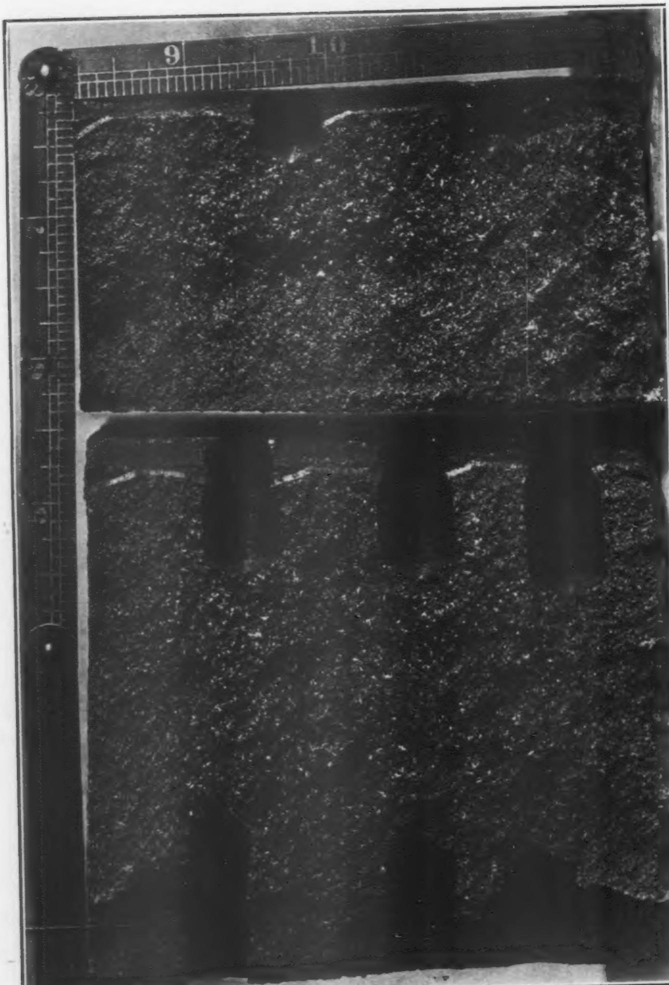

FIG. 9

in fact, all of the holes drilled with about equal ease. The metal was exceedingly tough and hard to break with the sledge.

Another heavy machinery mixture furnished by the Bethlehem Steel Co. is illustrated by bars 69, 70, 71, and 72, and a fracture of a large wedge cast from this metal is shown in Fig. 8. This wedge was chilled on one side, the chilled face being so hard that it could not be drilled. It will be noticed that the chill closed the grain for a distance of more than an inch from the surface. This metal is the lowest

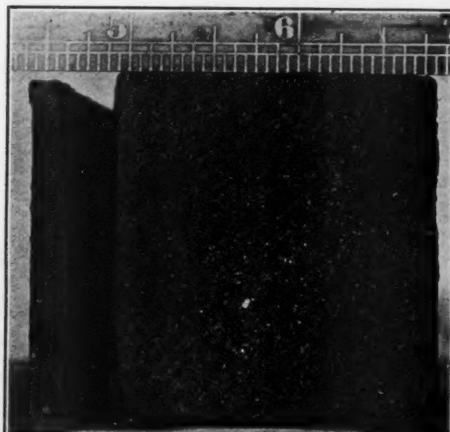

FIG 10

in silicon of any in the table, and is intended only for fairly heavy work. The drillings for analyses were taken from the center of an unchilled wedge about the middle of its length, and still showed .70 combined carbon.

The fracture of a large wedge unchilled is shown in Fig. 9, and it will be noticed that while the grain of the iron in the 4-inch section is exceedingly coarse that it is nevertheless well-knit together, forming a good strong casting. The

FIG. 11

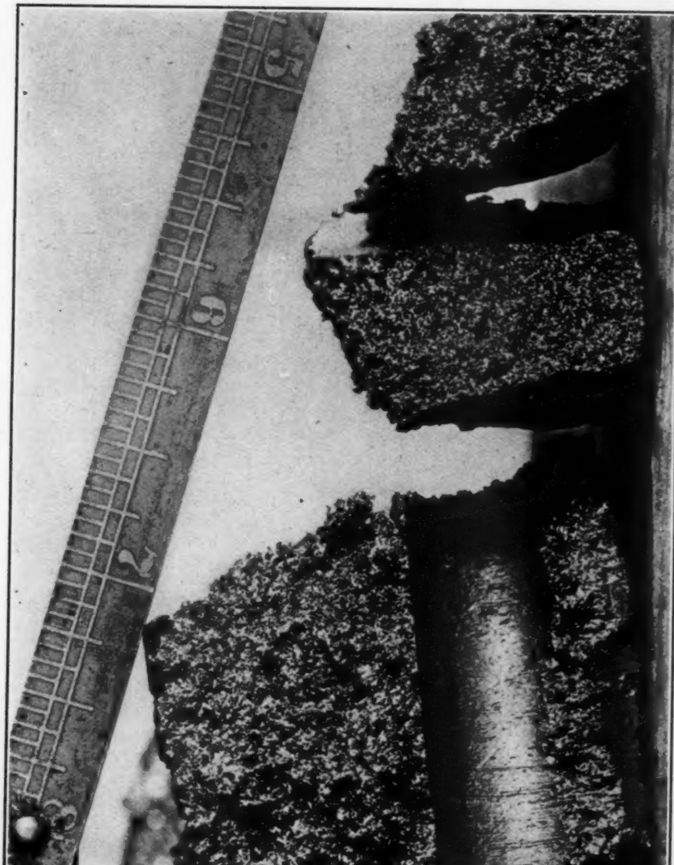

FIG. 12

difference in grain between the 2 and 4 inch sections is clearly shown in this illustration.

Another sample of iron furnished by the Bethlehem Steel Co. and used for a slightly different grade of castings is illustrated by Nos. 65, 66, 67, and 68. This iron is higher in silicon than the one above it in the table, and slightly stronger than the previous sample described. The fractures of a small wedge of this metal are shown in Fig. 10, which

FIG. 13

clearly illustrates the difference between the quarter inch and 2-inch section of material. The character of the fracture shows a good structure.

Among the samples furnished by Mr. Shennan and which were shown at Detroit, was a piece cut from the center of a riser 16 inches square at the point where it was cut off from the casting. This was separated from the casting by drilling holes about it and then drifting or chipping the metal away between the holes. The piece was subsequently broken and

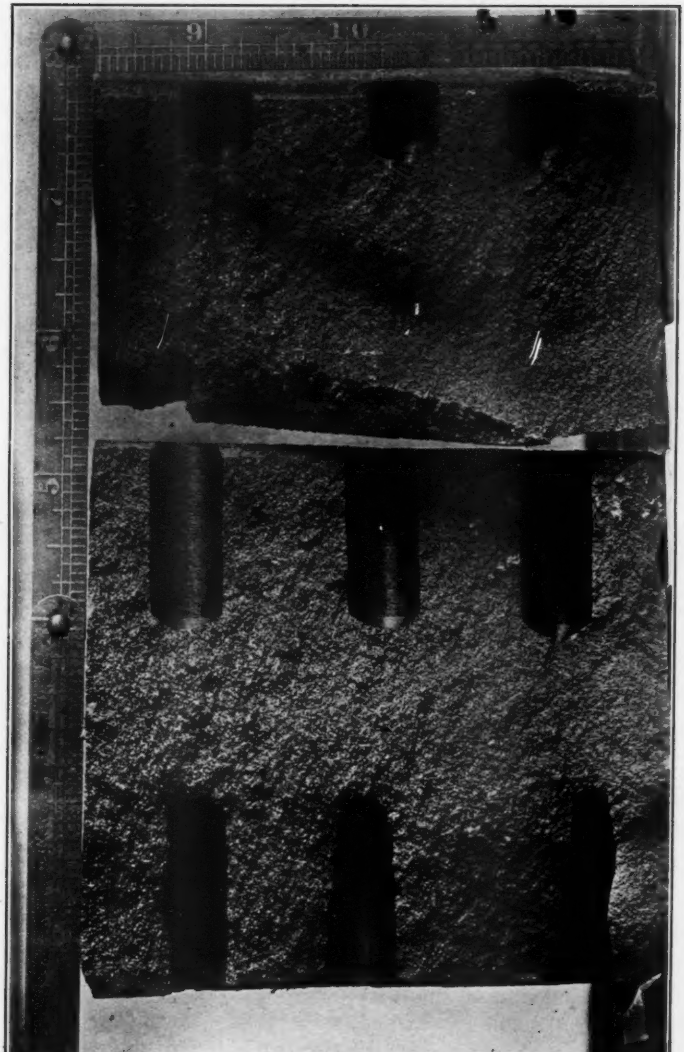

FIG. 14

the fracture at the center photographed, as shown in Fig. 11. The fracture near the outside of the same piece is shown in Fig. 12, and it will be noticed that there is a marked difference in the structure of the metal at these two points. At both points, however, the metal was well-knit together and of a grade which would commonly be called very good iron. The silicon in this particular piece was 1.23, which would be altogether too low for very light work. Metal of this kind is used for casting very large fly-wheels and similar parts.

FIG. 15

The last sample of machinery castings shown in the list is that furnished by the Taylor-Boggis Co., of Cleveland, and called by them gray iron. This is No. 96 in the table, and the fracture of the small wedge is shown in Fig. 13. This wedge is unchilled, and it will be noticed that the fracture of the large and small pieces does not vary much in texture. Both had fair machining qualities. A part of the secret of high grade iron of this kind lies in exceedingly careful melting as well as in careful selection of the stock. A specimen of the same grade of iron cast in a 4-inch wedge and chilled on one

FIG. 16

side is shown in Fig. 14, and in this case it will be noted that the center of the wedge well back from the chilled face is quite open in structure, while the fracture is good. The chill affected the metal much more deeply at the narrow end of the wedge than at the thick end, as shown in the illustration. This metal is intended for high grade gray iron castings, approximately an inch in thickness, though it would do very well for somewhat thicker work. The strength of the test bar it will be noticed is nearly 3,200 pounds per square inch.

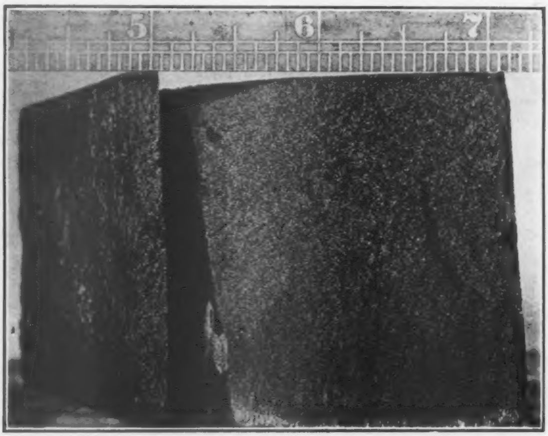

FIG. 17

We now turn to special irons intended to possess great strength or fitted for special purposes. The first specimens shown is what the Taylor Boggis Co. calls steel iron. This contains about 30 per cent. of steel in the charge. A fracture of both ends of one of the small wedges is shown in Fig. 15, and it will be noticed that this is very close grained metal. A fracture of the same metal poured into a large wedge is shown in Fig. 16. This wedge has been chilled on one side. By comparing the fractures shown in Figs. 14 and 16, it will be noted that the gray iron has a more open fracture at a considerable distance from the chill. The chilling also affected

the steel iron to a greater depth at the large end of the bar than in the case of the gray iron. The strength of the test bar shows the difference between the gray iron and the steel iron, the latter bar being over 3,700 pounds per square inch. An interesting point in connection with this bar is that the total carbon of the steel iron is considerably above that of the gray iron, and this clearly shows that it picked up carbon in the cupola. The silicon of the steel iron is considerably lower than that of the gray iron, which accounts for the closer grain and the higher percentage of combined carbon.

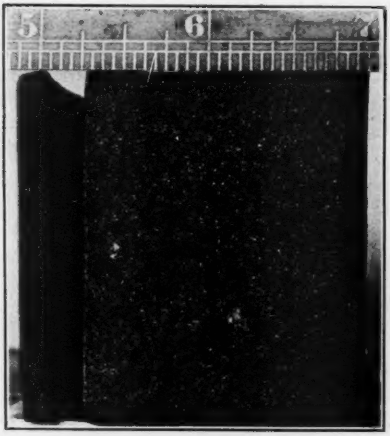

FIG. 18

An iron belonging in this same class was furnished by Mr. Murphy, of the Hooven Owens Rentschler Co., and was called by him semi-steel. This is represented by Nos. 38, 39, 40, and 41. A fracture of a small wedge is shown in Fig. 17, this bar having been chilled on one side, and it will be noticed that the chill shows distinctly white along the side of the bar. A similar piece unchilled is shown in Fig. 18, while a section of a 4-inch wedge chilled on one face is shown in Fig. 19. The character of the fracture at the large end of the 4-inch wedge shows plainly the way the iron is knit together.

FIG. 19

These wedges and test bars were cast from the ladle from which a 68-inch cylinder was poured, and two tension bars were poured from the same mixture and pulled. One of these broke at 37,225, and the other at 37,275 pounds per square inch. Mr. Murphy says that this iron would be too hard for small cylinders, but that it was very good for large work. For some special work he makes an iron that pulls as high as 40,000 pounds per square inch and sometimes higher.

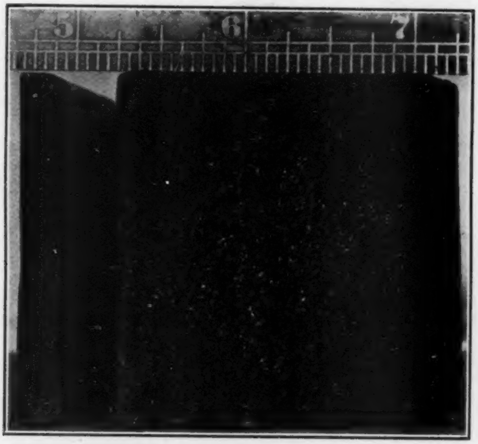

FIG. 20

Mr. Blundell, of the Taylor Boggis Co. had a tension bar of the steel iron shown in Fig. 15, pulled and it showed a little over 34,000 pounds per square inch.

Turning to another class of cylinders, we have bars Nos. 5, 6, 7, and 8, which were furnished by Mr. Becker, of the Root & Vandervort Engine Co. These represent their ordinary gasoline engine cylinder mixture, the engines being for the most part light and medium-sized agricultural gasoline engines. The fracture of two wedges of this mixture is shown in Figs. 20 and 21. The wedge shown in Fig. 20 was not

chilled, while that shown in Fig. 21 was chilled. Despite the fact that no chill was used on the wedge shown in Fig. 20, the corners at the small end were distinctly white and the metal exceedingly hard, showing that it would not be suitable for sections between ⅛ and ¾ inch provided these parts were to be machined. The sections in which the metal was cast generally ran from ½ inch to an inch in thickness. The chilled wedge shown in Fig. 21 has a distinct white chill along the face that was next to the iron chiller and at the same time

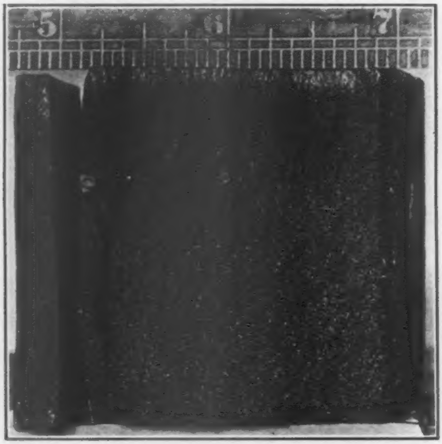

FIG. 21

on the small end shows a chill at the corner due simply to the character of the iron. The portion of the wedge furthest from the chill in Fig. 21 does not show a fracture differing materially from that shown in Fig. 20.

In making cylinder mixtures a very good idea of the quality of the iron can be obtained by pouring a sample into a small iron mold, cooling it quickly and breaking it. The depth of chill will give a very good indication of the quality of the metal. Mr. Murphy uses this method for testing his semi-steel mixture for large cylinders and can tell by the fracture of the chilled specimen when all of the steel is melted

and in the ladle. For thoroughly mixing the metal in the ladle he frequently uses a wooden pole, which is forced down

FIG. 22

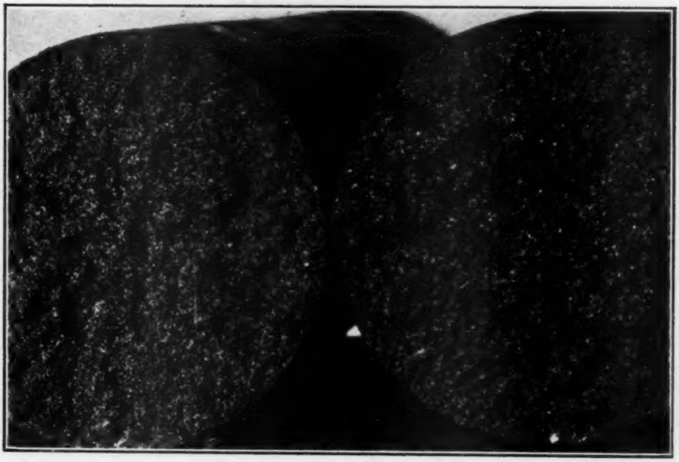

FIG. 23

into the molten metal and mixes it thoroughly. On cylinder mixtures and similar iron the foundryman can check his cupola practice very closely by inspection of chilled pieces.

Fig. 22 shows the fracture of two test pieces of cylinder iron made by Mr. Murphy, of the Hooven Owens Rentschler Co. The one on the right was cast when the ladle of cylinder iron was about two-thirds full, and at the same time the test bar on the right in Fig. 23 was cast. The piece on the right of Fig. 22, shows gray in the center, which indicates that all of the steel in the charge had not been melted. The piece

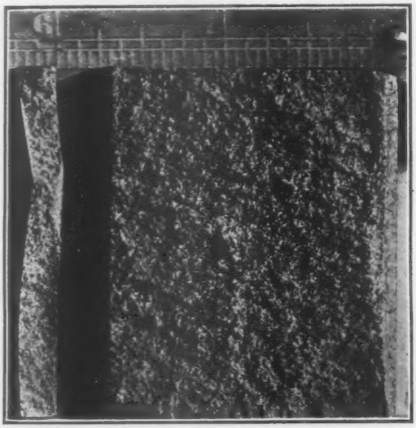

FIG. 24

on the left in Fig. 22 was cast after the ladle was full, and its composition shows that all of the steel was melted and mixed with the molten metal in the ladle. The bar on the left in Fig. 23 was cast at the same time. Both of the bars were broken and the one on the left was about 400 pounds stronger than the one at the right.

A cylinder mixture used for automobile work by J. J. Wilson, at the Leland Falconer plant of the General Motors Co. is illustrated by Nos. 75, 78, 79, and 80. It will be noted that the fracture of the wedge cast from this mixture is shown in Fig. 24, and it will be seen that at the large end of the wedge it has an exceedingly open, though closely-knit fracture, while at the small end the fracture is dense but shows no chill about the corners. The walls of these automobile

cylinders vary from $\frac{3}{16}$ inch in the water jackets to a little over $\frac{5}{16}$ of an inch in the bore, and it is probable that in most cases no part of the casting is over half an inch thick except where bosses occur. For strength and to resist cracking in service no part of the casting must show any chill and at the same time the metal must be strong and uniform. This is certainly one of the most difficult propositions that can be put up to a foundryman, and it is only by very careful melting and careful cupola practice that good results can be obtained in this class of work.

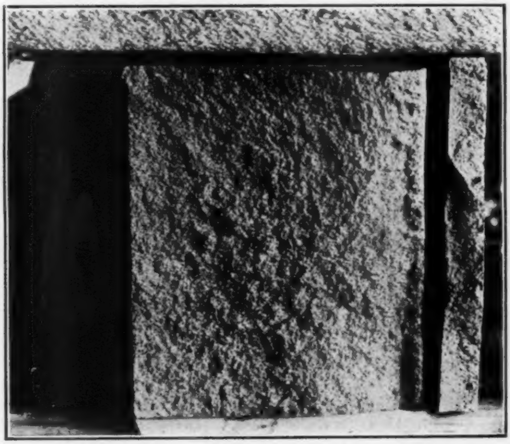

FIG. 25

In many automobile foundries the piston rings are cast from the same mixture that is used for the cylinders, but it is better practice to use a separate mixture. The ring mixture used by Mr. Wilson of the Cadillac plant, is illustrated by Nos. 74, 81, 82, and 84. Fractures of both ends of a wedge of this mixture are shown in Fig. 25, which clearly illustrates the close grain of this metal even when cast in the relatively large section at the two-inch end of the wedge. The silicon in this mixture is slightly lower than that in the cylinder mixture, while the sulphur is higher and the phosphorus

double that used in the cylinder iron. In the analyses given in the table the combined carbon is lower than that given in the cylinder iron, but the reason for this is that in both cases the drillings were taken from the center of a wedge, and not from the section in which the metal is to be poured. The combined carbon in the ring castings themselves will generally run at least .85.

A piston ring is a spring, and hence must contain as much combined carbon as there would be in a steel spring that is not less than .65 per cent. of carbon, which would all be in the combined form. A cast iron piston ring may be considered as a steel spring containing such impurities as silicon, sulphur, phosphorus, manganese, and graphitic carbon. The graphitic carbon gives wearing qualities to the spring, but it is the combined carbon which gives the elasticity. Ordinary phosphorus is supposed simply to promote fluidity in the molten metal, but when present in considerable quantities is undoubtedly a hardener, and may assist in imparting good qualities to the ring. Piston rings should be cast with as little stock to be turned off as possible, and the mixture proportioned to give the proper amount of combined carbon in the thickness of the casting as it leaves the foundry.

It is not alone in the case of piston rings that the physical properties of the metal are affected by the thickness of the casting and the rate of cooling. Many foundrymen are convinced that the acid-resisting properties of castings depend more upon their physical structure than upon their chemical composition. A hard close grained casting into which the fluid can not penetrate will resist either acid or alkali much better than a soft open spongy casting. In the case of pots used for caustic soda, failure generally occurs by the pot being eaten through in certain spots, and examination always shows that these spots were for some reason slightly more porous than the remainder of the metal. Frequently a little dirt in the casting or a small blowhole will start action of this kind. This is also particularly true in the case of pumps which must resist acid waters, as for instance, in mine work.

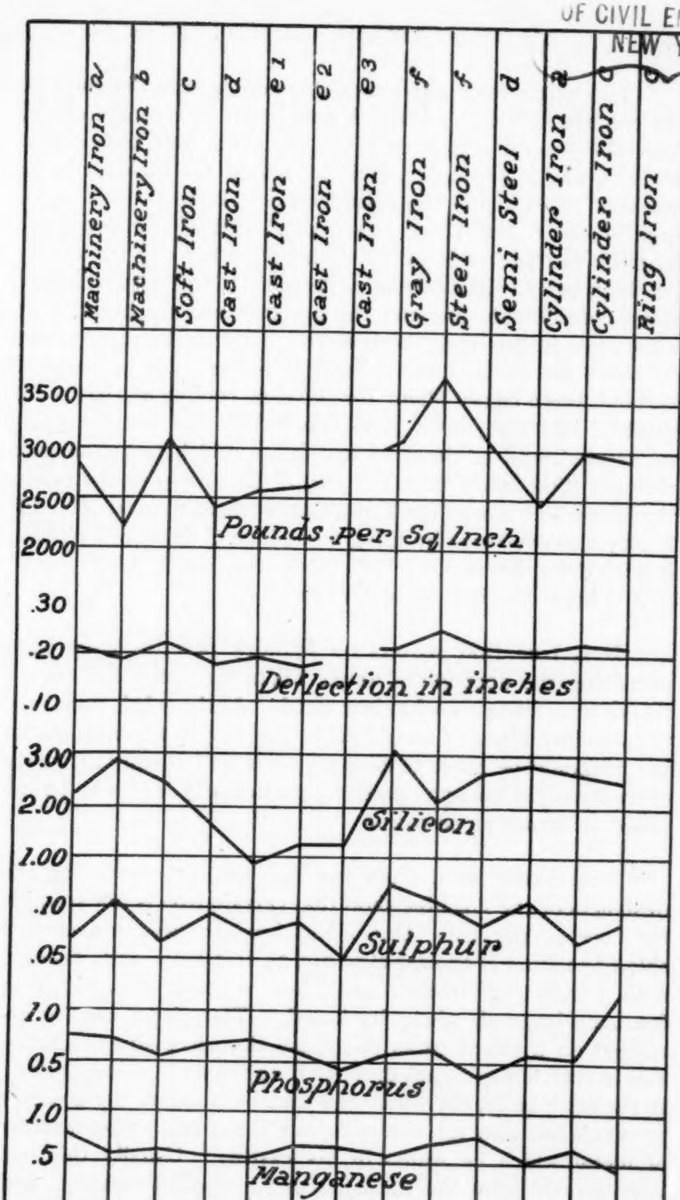
Machinery Iron a
Machinery Iron b
Soft Iron c
Cast Iron d
Cast Iron e 1
Cast Iron e 2
Cast Iron e 3
Gray Iron f
Steel Iron f
Semi Steel d
Cylinder Iron a
Cylinder Iron
Ring Iron
3500
3000
2500
2000
Pounds per Sq Inch
.30
.20
.10
Deflection in inches
3.00
2.00
1.00
Silicon
.10
.05
Sulphur
1.0
0.5
Phosphorus
1.0
.5
Manganese

FIG. 26

The writer remembers a double-acting pump in the coal regions, the cylinders for which were made by a local foundry and this pump had to have new cylinders at least every three months, and sometimes a cylinder would eat through in six weeks. The walls of the cylinder were about an inch and a quarter thick, but there was a dead end of division plate between the two ends of the cylinder midway of its length. As this was a flat plate about 14 inches in diameter, and had to resist considerable pressure the designer had thickened it to about two inches and placed heavy fillets at the place where it joined the walls of the cylinder. Failure always occurred through these heavy fillets, for the slow cooling at that point resulted in large shrink holes into which the water quickly penetrated, and at times an opening would be eaten around through these fillets from one end of the pump to the other, through which a man could run two or three fingers. The difficulty was overcome by using a one-inch division and ribbing it with deep ribs about $\frac{7}{8}$ inch thick, very small fillets being used where the ribs joined the division.

It is true that writers on foundry practice have been preaching the doctrine of ample fillets for years, but curves rather than fillets are what is wanted. At times it is necessary to introduce fillets of considerable size, but in all cases an attempt should be made to keep all parts of a casting as nearly of uniform thickness as possible, particularly if it is to be exposed to strain or corrosion.

The foundryman often has difficulty in convincing the designers or the machine shop that certain iron is not suitable for a certain purpose. One of the simplest ways to overcome this opposition is to cast a wedge $2\frac{1}{8}$ feet long, and tapered from $\frac{1}{8}$ inch to $2\frac{1}{2}$ inches, and then to break this wedge at frequent intervals along its length. The pieces can be arranged on a board so as to expose the successive fractures, and in such a way as not to make it apparent that they belong to the same piece, the whole can then be taken to the designer or machinist and let him pick out the grade and character of metal which he wants in his casting. Usually this will vary greatly from the thickness of the desired castings, and

all that the foundryman has to do to convince him that the grade is wrong for the thickness desired is to fit the pieces of the wedge together and show that it is of a similar metal. By casting two or three wedges of different grades of iron it is possible to arrive at a definite conclusion as to what is wanted. If necessary the machine shop can experiment on parts of the wedges to find which metal has the best machining qualities.

A little work of this kind together with co-operation between the designing end, the foundry, and the machine shop, will result in better metal in the finished product, in the lightening of castings, and in the saving of considerable expense to the firm. It is true that the product of some shops is sold by the pound, and in such cases the tendency is to put in all the iron that the traffic will stand, losing sight of the fact that the public will ultimately place its trade with the firm furnishing the machinery or equipment best suited for its work, and that the short-sighted policy of clumsy construction for the sake of heavy castings is a poor one. Quality in foundry practice, as in every thing else, counts, particularly in the case of the higher grade castings.

It has taken much careful educational work to convince the leading manufacturers of machine tools and other devices that high grade stock is an advantage in their work, and foundrymen throughout the country still have much pioneer work of this kind to do. The foundries which are getting the highest price for their work are working on this quality line, however. When a machine tool builder finds that he can obtain uniform castings which will machine easily, do not overrun in weight, and at the same time are so strong that he can design lighter than he would with ordinary cast iron, he is generally willing to pay a fair premium for such work, and in cases where he is not yet educated up to this point it is the duty of the progressive foundryman to do the educating.

When this paper was started it was the intention to cast test bars of a number of different diameters and both square and round from several of the mixtures, in order to show the

market effect on the strength per square inch, which would result from the use of different styles and sizes of bars, but time has not permitted the completion of this part of the work. It is sufficient to say that such mixtures as the piston ring iron and cylinder iron when cast in small bars which have a tendency to chill would show a much higher strength per square inch. The relatively large bar was selected so that it might be a mean between the thickness of the different kinds of castings made in foundry practice.

In the case of castings of considerable cross section slow cooling of the thick parts results in the segregation of the metal in these parts and also in the formation of shrink holes. A difficulty of this kind is sometimes overcome by placing iron bars in the mold in such a way that the ends of the bars project into the thick parts of the metal, thus acting as internal chills, the bars themselves being melted or softened to such an extent that they unite with the surrounding iron and form a solid casting. In work of medium size, nails are frequently introduced into hubs or bosses in this way, and these may result in overcoming shrink holes or spongy spots.

Another method of obtaining a solid boss is to use a cast iron core which is partially melted and unites with the surrounding metal. This is especially advantageous when such parts have to be penetrated by boring or other machine operations which would expose any defects in the metal. Of course when metal is poured very hot there is danger of these cast iron cores being melted off and the relatively cool metal being washed into some thin part of the castings, thus aggravating the evil that it was intended to cure.

Another handy method of judging the character of an iron is by taking a sprue or test bar, having it turned up in a lathe, and polishing with emery cloth and oil. The polish which iron will take depends very nearly upon the percentage of combined carbon. An open grained iron high in graphite takes a very indifferent polish, while a fine close grained metal will take a high polish. A little experience in this manner will enable a man to judge very closely the amount of combined

carbon in the metal and in testing new iron or new mixtures we have frequently known this method to be adopted for comparing the new with the old or standard mixture. Of course chemical analysis should be used in determining the quality of raw materials, and it is well to have the assistance of the chemist in making up the mixture and outlining the cupola practice, but the best mixture the chemist can give you can be ruined in the melting and this can be done either by using too much or too little coke. In the former cast the melting takes place too low, that is, below the melting point of the cupola, where the iron is rapidly oxidized, which will render any iron weak. If too much coke is used the melting takes place slowly at the top of the melting zone, the iron is exposed for a much longer time to the action of the sulphur in the fuel, as when melted it descends slowly through a greater height of the cupola than it would have to fall through were the melting taking place at the proper point. Melting high also exposes it longer to the air blast for oxidation and generally the slow melting exposes it longer to the slag for the absorption of sulphur.

Also when an excess of fuel is used there is an excessive amount of ash in the cupola which results in more slag and more sulphur to be absorbed by the iron. While it is chemical elements that are responsible for the bad results in these cases it is the mechanical mistakes of wrong charging which have ruined the metal.

As David McLain, of the Milwaukee Correspondence School has frequently said, "All irons are good irons," but each one has its use, and the physical properties both of the metals entering the mixture and of the final metal itself, as melted, will determine the use for which the iron is fitted. The foundryman who attempts to cast work outside of the range for which the iron is fitted is only inviting disaster.

President Waterfall. "Is there any discussion on Mr. Lane's paper?"

Mr. Putnam. "Mr. Lane in speaking of piston rings brings up the point that they should be as near like steel as possible. That is a very good theory, but we have found that in practice it does not work out very satisfactory. We have found that the piston ring that contains one-tenth of one per cent. of silicon, gave better results than the suggestions here in Prof. Porter's paper. These are elements I do not think Mr. Lane has in mind. Leaving out of the discussion the question of carbon, the two elements that seem to give better satisfaction is to raise your sulphur and your phosphorus and keep your silicon about one and one-half per cent."

Mr. Lane. "Dr. Porter gave the carbon matter all right. I know some people who cast the ring of the automobile cylinder and raise the sulphur in it by taking out the metal and melting it over as a piston ring mixture. Phosphorus does, undoubtedly, harden the iron and that would have some effect. You can get the same effect with sulphur without any carbon in it at all. By having the three elements properly prepared, you can get a very good strength."

The convention here adjourned until Thursday A. M., at eleven o'clock.

PLEASURE BOAT RIDE ON THE DETROIT RIVER

The afternoon of Wednesday was spent in a most enjoyable boat ride on the Detroit River. The splendid day, the finest steamer on the river, and the jolly gathering made the occasion a memorable one. The river is most picturesque, and running through historical ground allows one to conjure up most fanciful pictures of the early struggles of the French and Indian wars. Passing along beautiful "Belle Isle," and nearly up to the St. Clair River, and then down again below Detroit, the steamer was stopped at the great works of the Semet-Solvay Coke Co., where those who wished to see the making of by-product coke at first hand, were given

the best opportunity they could get anywhere. While this inspection was going on the rest of the party went on with the boat to the immense excavating operations of the Government for the Livingston Channel. Returning again, Detroit was reached by a tired, but happy crowd. Later in the evening the steamer was again put at the disposal of the Associations, and a merry party of foundrymen and their better halves enjoyed the beautiful moonlight evening sailing through a veritable fairyland. Dancing, music, and the interchange of thought and sentiment brought this most interesting day to a close, with the warmest thanks of all who had enjoyed the hospitality of the good Detroit Foundrymen.

FOURTH SESSION

Thursday, June 9, 1910. 11 *A. M.*

The meeting was called to order by President Waterfall who said: "Before proceeding with the paper of the session I will now announce the nominating committee for the election of officers of the American Foundrymen's Association.

W. H. McFADDEN, Pittsburg.
L. L. ANTHES, Toronto.
JOS. J. WILSON, Detroit.
ALFRED E. HOWELL, Nashville.
H. A. CARPENTER, Providence.

"I would like the committee to get together as soon as possible so that to-morrow's business session can have the report.

"I will also announce the auditing committee to comply with the resolution passed yesterday that the Doctor would have to have an auditing committee or else he would be giving all his salary to us.

HERBERT E. FIELD, Pittsburg.
WM. YAGLE, Pittsburg.

"Pittsburg men are put on because the business of the convention being held there next year—or at least it looks that way now—it will save considerable expense and a lot of time.

"The first paper of this session is on the 'Shockless Jarring Machine' by Wilfred Lewis, of Philadelphia, Pa."

THE SHOCKLESS JARRING MACHINE*

By Wilfred Lewis, Philadelphia, Pa.

In this paper the following subjects have been treated: Paragraphs

*Presented simultaneously to the American Society of Mechanical Engineers and the American Foundrymen's Association

THE SHOCKLESS JARRING MACHINE

1. The title of this paper may appear to the casual reader like a contradiction of terms, but to the foundryman who has hitherto attempted to ram sand by the jarring process, the term "shockless" will be understood to apply only to the foundation or support on which the machine stands.

2. The jarring machine is essentially a sand-packing machine, capable of ramming any mold, large or small, in a minute or less time, and by the method employed, the sand is rammed as it should be, densest at the surface of the pattern and of decreasing density above, thus favoring the escape of gases when the mold is poured. The packing of the sand results from impact between the table on which the mold is carried, and the anvil on which it drops, and in operation, various means may be used to lift the table and let it drop, but in foundry work compressed air has come to be generally preferred for its convenience as a medium for the transmission of power, and also for the simplicity of the machines resulting from its use. The jarring machine is not universal in its application, nor should it be used without judgment and discrimination. Due regard must be given to the construction of the pattern, so as to permit a flow of sand chiefly in one direction, and to withstand successfully the shock of impact in ramming. But, for the broad field of work adapted to its use, there is nothing comparable to the jarring machine as a saver of time and money.

DEVELOPMENT OF MACHINE MOLDING

3. Jarring machines have been in practical use for many years, without attracting much attention, and the records of the patent

office go back to 1869, but like all other types of molding machines they have never been made, until quite recently, for large heavy work beyond the strength of one or two men to handle. It was quite natural that the molding machine should begin its development in a small way, on small work, and gradually extend its field of usefulness to larger and heavier molds, and as the field has widened, it has been seen that the possibilities for saving time and money in the foundry have increased with the size of the work adapted to machines.

4. Any one who has watched a bench molder fill his little flask, ram it in a few seconds with a butt rammer in each hand, then roll over and draw the pattern with the dexterity of an artist in legerdemain, can appreciate the difficulty of helping him in his work by any mechanical means. And yet the old-fashioned hand squeezer saved some of the ramming time, the power squeezer saved a little more, but not so much in time as in the strength of the operator, keeping him fresh with steady hand and eye for the delicate work of drawing patterns and setting cores. Pattern guides were then devised to assist in drawing patterns and vibrators were invented to free the pattern from the sand without appreciably enlarging the mold.

5. The use of molding machines on small work has resulted in a substantial saving in the cost of molding, less wear and tear on patterns and greater uniformity in castings, the saving in weight of the castings due to the use of a vibrator being sometimes an item that soon pays for the installation of machines.

6. The hand squeezer is, of course, limited in its application to what can be done at one effort by one man, and for larger work, power squeezers have generally been employed, but when large molds are squeezed by power, more or less trouble has been encountered in the distribution of pressure on the sand and at one time an effort was made to overcome this difficulty by means of a water-bag, placed between the sand and the squeezing head. Better results were obtained, however, by judicious tucking in deep pockets and by heaping the sand over deep places and scooping it out over high points in the pattern, but the main difficulty in squeezing deep molds

lies in the fact that the sand is generally moved against the pattern, instead of the pattern against the sand. This results in the greatest density of sand being away from the pattern next to the squeezing head, and not where it should be next to the pattern.

7. As shown by Harris Tabor's experiments, which were presented to the American Society of Mechanical Engineers in 1892, the friction of sand on the sides of a deep flask may carry a large part of the pressure on the squeezing head. To avoid this difficulty, bottom ramming machines have been employed which move the pattern against the sand, but this method contemplates a definite predetermined movement of the pattern to produce a mold of the density desired, and it is subject to variations not easily controlled. Bottom ramming has, therefore, not been adopted to any great extent, and power squeezers have been limited in size to flasks not often more than 2 or 3 feet on a side by a foot deep. Such machines, when designed also for pattern drawing, are comparatively expensive, and they marked for a time the limitations of machine molding.

8. During recent years, however, while the power squeezer and the split pattern machine were completing their development, the much neglected jarring machine has grown steadily in favor and in size until to-day there would seem to be no limit to its capacity. These machines are simple in construction and effective in operation, while on large work the saving to be effected by their use probably exceeds that of all other types of molding machines combined. I say on large work, because on small work jarring machines cannot compete with power squeezers of the same capacity, except perhaps in a few special cases where the work is deep.

VALUE OF LABOR-SAVING APPLIANCES

9. The value of any machine depends, of course, on what it can save and what it costs to effect that saving, and this is a problem to be worked out in every instance by a systematic time study of all the operations embodied in producing a given result. For instance,

if it takes two men eight hours to mold by hand a certain pattern in a flask 45″ × 60″ × 36″, and if five hours of this time are consumed in ramming sand, a jarring machine would save practically five hours of that ramming time. It would not save any of the pattern drawing and finishing time, nor any of the time for setting cores, but it would enable two men to make the mold in three hours instead of eight hours by hand, hence with a suitable jarring machine, two men could put up 2.67 times as much work as by hand.

10. In this case the jarring machine saves more than half of the molding time, and it is, therefore, the most important help in the reduction of cost, but when patterns are rapped with a sledge and drawn with a crane or hoist, a great deal of the molder's time may be taken up in finishing, or, to put it more bluntly, in repairing the damage done to the mold by this brutal way of rapping and drawing the pattern. Assuming that about one hour might be spent in finishing each half mold when made by hand, an effective pattern drawing machine could easily save two hours, and with such a machine, it is evident that two men could make a mold in six hours, thus increasing their rate of molding 1.33 times that done by hand. By means of a sand conveyor or even a clam-shell bucket on a traveling crane, perhaps 30 minutes could be saved, thus enabling two men to make the mold in 7 hrs. 30 min. and with this device only they could make their rate of molding 1.067 times as fast as by hand.

11. For the purpose of illustrating the advantage of co-operation or concentrated effort upon any given piece of work, let us assume that the demand for the castings, above referred to, has resulted in the making of three sets of patterns, and that we have three sets of men at work making three molds a day by hand. Now, suppose we give one set of men a jarring machine, another set a pattern drawing machine, and the third set a sand conveyor.

The first set of men will produce in 8 hrs.	2.67	molds
The second set of men will produce in 8 hrs.	1.33	molds
The third set of men will produce in 8 hrs.	1.067	molds
Six men with three patterns will produce	5.067	molds

in 8 hours instead of three molds by hand or about 1.7 times as much work.

12. On the other hand, if we have but one pattern and one set of men, and give them the combined help of a jarring machine, a pattern drawing machine and a sand conveyor, two men will save 5 hours in ramming time, 2 hours in finishing time and half an hour in shoveling sand, or $7\frac{1}{2}$ hours in all, bringing the time down on one mold from 8 hours to 30 minutes, and increasing the production sixteen times. In other words, the same assistance concentrated for the benefit of two men will result in more than three times the production at less than one-ninth the cost per mold.

13. The above illustration shows not only the advantage of concentrated effort in the use of labor-saving appliances, but also the wide difference in results that may be realized from the same appliances in different hands. Not only does the concentrated effort in this case save the wages of four men, and produce three times as much work, but it also distributes all of the indirect charges, which must ultimately be carried by the product, over a larger output. So much for the savings to be effected.

14. So much for the savings to be effected. On the other hand, the interest on the investment, the depreciation of the machine and the consumption of power must be accounted for, and in addition to all these, the damage that may be caused by the action of the jarring machine upon finished molds or even upon buildings in the neighborhood, and the annoyance caused by noise and ground waves generally. This damage and annoyance has increased steadily with the increase in the size of machines and the weight of the loaded table, and to meet these serious objections, various expedients have been adopted, among which may be mentioned a reduction in the stroke or drop given, and a more or less resilient bedding for the anvil.

PRINCIPLES GOVERNING THE DESIGN OF A JARRING MACHINE

15. These palliatives, however, left much to be desired, until the shockless jarring machine with its uprising anvil to meet the

falling table was developed. This has eliminated the chief objection to jarring machines, and it is the object of this paper to elucidate the principles upon which it works and to establish its superior claim to efficiency in the consumption of power.

16. In the first place it must be admitted that, although the packing of sand by the jarring process is very quick and effective in producing results, it is not very efficient under the most favorable conditions as far as the expenditure of power is concerned, and that under certain conditions the efficiency may be reduced to zero. In the process of ramming, the density of sand is increased 25 or 30 per cent., and if a steam indicator were attached to the cylinder of a power squeezer, it may be questioned whether the work actually done on the sand in squeezing it to proper density would ever exceed 1,000 ft. lbs. per cubic foot. Of course, a great deal more power than this would be consumed in the use of water or air as a working fluid, but the work put into the sand would in all probability not exceed 1,000 ft. lbs. per cubic foot.

17. To produce the same effect by jarring, the sand might be raised to a height of 4 inches and dropped upon an anvil thirty times, but, in addition to the weight of the sand, must be added the weight of the table, flask and excess sand to aid in ramming. The first blow struck will cause the greatest flow of sand, and will do the most work upon it, while each succeeding blow will increase the density and do less and less work until, after a certain number of blows, the sand will remain at a density corresponding to the drop, and when this point has been reached, the continued action of the jarring machine simply wastes power and produces no effect. The jarring machine is, therefore, more efficient during the earlier stages of the process than it can be when the condition of maximum density is approached, and for this reason the longer the stroke, the greater the efficiency, but other considerations of a practical nature affecting the elasticity or durability of flasks, patterns and the machine itself, necessarily tend to limit the stroke, so that in practice it varies from 3/8 inch on some machines to 4 inches or more on others with an average of perhaps 2½ inches.

18. In such machines, the most important consideration is solidity of construction and freedom from vibration in the jarring table.

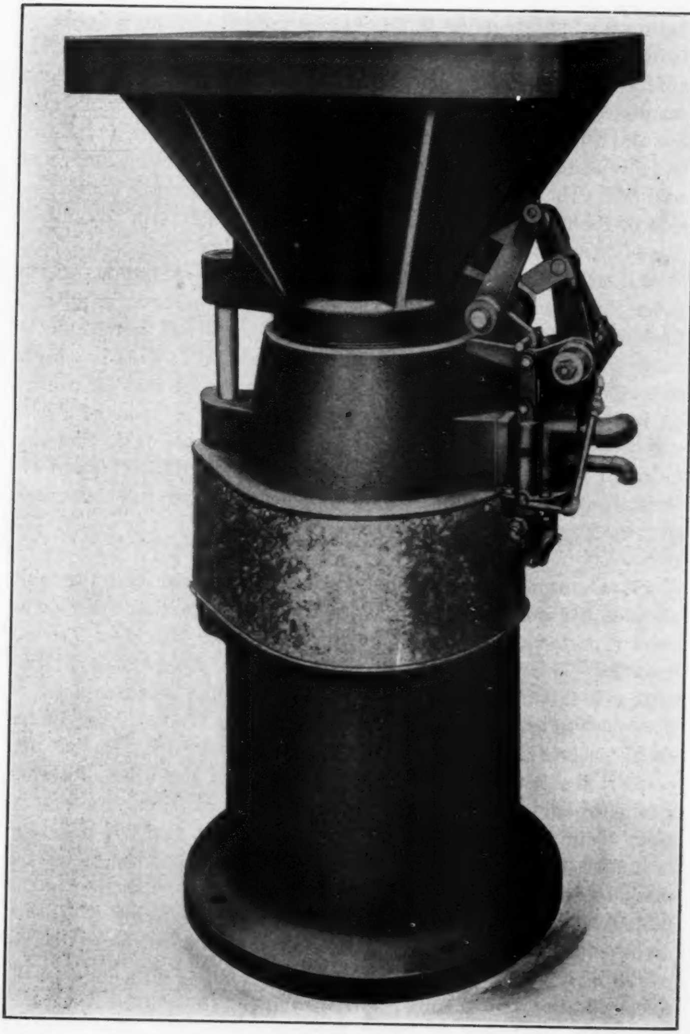

FIG. I

Otherwise the sand will become broken or laminated in character and the mold will be liable to fall apart in handling. Although lightness of construction in the jarring table is obviously desirable from the standpoint of economy in power, it is certainly not desirable from the standpoint of making perfect molds. The good results which accompany the stronger and stiffer table, really cost less and consume less power in the end, because there are no failures to be repeated nor molds to be thrown away. The importance of solidity in the jarring table will be appreciated from a consideration of the character of rammed sand. It has a certain amount of elasticity, a good deal of resistance to further compression and some tensile strength which, of course, is easily overcome. There must therefore be no movement between the pattern, sand and flask, tending to pull the sand apart, of sufficient amplitude to cause fracture, and no lateral movement tending to slide one layer of sand over another. Such fracture or lamination may be caused by badly fitted pattern boards, flimsy patterns or crooked flasks not properly bedded, but a light and flimsy jarring table that can be easily warped out of shape will augment the difficulty, and effectually prevent the success of good patterns carefully mounted in strong and firmly bedded flasks.

19. In the molding machine which is being described, the table adopted has been formed in one piece with the jarring cylinder as shown in section by the line drawing of the shockless jarring machine. This table has great depth of beam, the metal is distributed as it should be for economy of cast iron, in a broad expanse of plate on the tension side, and a smaller mass around the cylinder on the compression side, where the blow is struck. Radial ribs connect the tension and compression sides of the beam, forming a table of enormous strength and stiffness to distribute the central blow of impact equally in all directions, and a table of this type is really stiffer than some of the anvils on which other tables are made to drop. At any rate, there is no perceptible vibration of the table when it strikes its anvil, or rather the buffer ring of leather or other non-resilient material interposed to relieve the sharpness of the blow and to reduce the noise. This buffer also helps to reduce vibration and rebound by reducing the intensity of the force of impact. It is not, however, the rebound of the table from its anvil that injures a mold so much as the rebound of the flask and

sand from the table. Solidity of contact between the table, pattern board and flask is one of the most important elements forthe successful working of a jarring machine, and yet this detail rarely receives the attention it deserves, and not infrequently the machine is sometimes condemned for a cause which is no fault of its own.

20. As already stated, unlimited power may be expended in jarring sand to any given density, and since there is a certain maximum density corresponding to any given drop, it is also quite evident that efficiency increases with the drop and decreases with the dead weight handled over and above the weight of sand used. But a certain amount of dead weight is inseparable from the process, and for this reason a heavy machine may not be used to its best advantage on light work. Nevertheless with air as a working fluid, the benefit gained by expansion on light work offsets to a great extent the loss from the greater proportion of dead weight carried, and gives to the jarring machine which uses air expansively in its cylinder quite a wide range of capacities under approximately uniform efficiency, as far as the consumption of air per cubic foot of sand rammed is concerned.

21. But it is not only the air consumed in lifting the loaded table that may not be utilized to the best advantage, for at the instant of impact when the loaded table strikes its anvil, the sudden change in the velocity of the table, whatever that may be, measures the pressure of impact, and the ramming effect is measured by the square of that change in velocity, which is proportional to the energy absorbed, part of which is utilized in ramming sand. Therefore, the greater the change in velocity at the instant of impact, the greater the ramming effect, and by the laws of impact, the heavier the anvil, the better. Efficiency in a plain jarring machine naturally increases with the weight put into the anvil, but since the cost of the machine depends very largely upon the weight of cast iron or concrete used, the weight of the anvil is generally limited to that of the loaded table, and when such anvil is bedded on rock, it becomes practically of infinite weight and capable of developing the maximum ramming effect for any drop given to the table. A rock bottom does not, however, eliminate the destructive ground waves and often facilitates their transmission to un-

usual distances, and to mitigate the effect of these shocks, the practice has been to bed the anvil on a timber cribbing after the manner employed for steam hammers.

EFFICIENCY DEPENDS UPON THE ANVIL

22. So cushioned, the anvil when struck by a loaded table of its own weight will suddenly acquire one-half of the velocity of the table at the instant of impact, after which both table and anvil will be brought to rest by the yielding resistance of the timber cribbing, and they will then be returned by its elasticity to their normal position. The loaded table, in this case, loses at the instant of impact only one-half of the velocity it would lose by falling upon an anvil of infinite-weight, as exemplified practically in an anvil founded on rock. Following this, the retardation of the table by the compression of the wooden cribbing is less intense and less effective in ramming sand, although this second change in velocity, no doubt, has some effect, especially in the earlier stages of the ramming process while the sand is comparatively soft. Nevertheless, the initial change in velocity between a loaded table and a floating anvil of equal weight is only half as great as the change in velocity of a loaded table falling the same distance upon an anvil of infinite weight, and the ramming effect in the first instance being measured by the square of the change in velocity is only one-quarter as much as in the second case, where the whole energy in the falling mass is immediately absorbed.

23. An anvil cushioned upon a wooden crib may be considered as a floating anvil in which the supporting medium is very dense and highly resistant, but in which also the resistance to compression is trifling compared to that of rock. The stiffness of such an elastic bedding for an anvil might be estimated from the anvil movement, of which no data are at present available, but however effective it may be in the initial stages of the jarring process, it can have but little if any effect upon the final stages after the sand has been rammed to a density in excess of that corresponding to such elastic resistance. It may be said, therefore,

without hesitation that anvils cushioned upon wooden cribbing are much less effective than anvils founded on rock, and that such anvils, equal in weight to the loaded table, have in the final stages of the jarring process a comparative efficiency of only 25 per cent.

24. In considering the mechanical efficiency of a jarring machine, it is therefore a matter of some importance to provide an anvil of maximum efficiency for any given weight. As a matter of course the heavier the anvil in any case, the better, and the unit standard for all anvils may be one of infinite weight comparable to a foundation on rock. Such an anvil stands for the highest attainable efficiency, but it is not a practicable construction on account of the destructive ground shocks, which the shockless machine eliminates, and we shall presently see how the anvil in this machine compares in efficiency with the usual type of anvil mounted on a wooden crib.

GENERAL DESCRIPTION OF THE SHOCKLESS JARRING MACHINE

25. The shockless jarring machine consists in its usual form of a jarring table mounted upon an upstanding plunger forming the anvil, which in turn is mounted in a cylinder base and supported upon long helical steel springs. Compressed air, as the working fluid, is admitted through an automatic valve, under hand control attached to the plunger or anvil base, and this passes first into the jarring cylinder to raise the loaded table. At some predetermined point in the table movement, the air is automatically cut off from the cylinder, and while the valve is reversing, the confined air will expand and lift the table further from its anvil, if its initial pressure exceeds the balancing pressure due to the weight carried. Then, when the operating valve completes its reverse movement, the air from the jarring cylinder may be exhausted into the atmosphere, but preferably it passes from the jarring cylinder to the anvil cylinder beneath, and the table drops by gravity against the reduced pressure in its cylinder. At the same time the plunger base or anvil is relieved of a considerable part of the load carried by its supporting springs, which immediately expand, giving the anvil an upward velocity to meet the falling table. When air is expanded from the jarring cylinder into

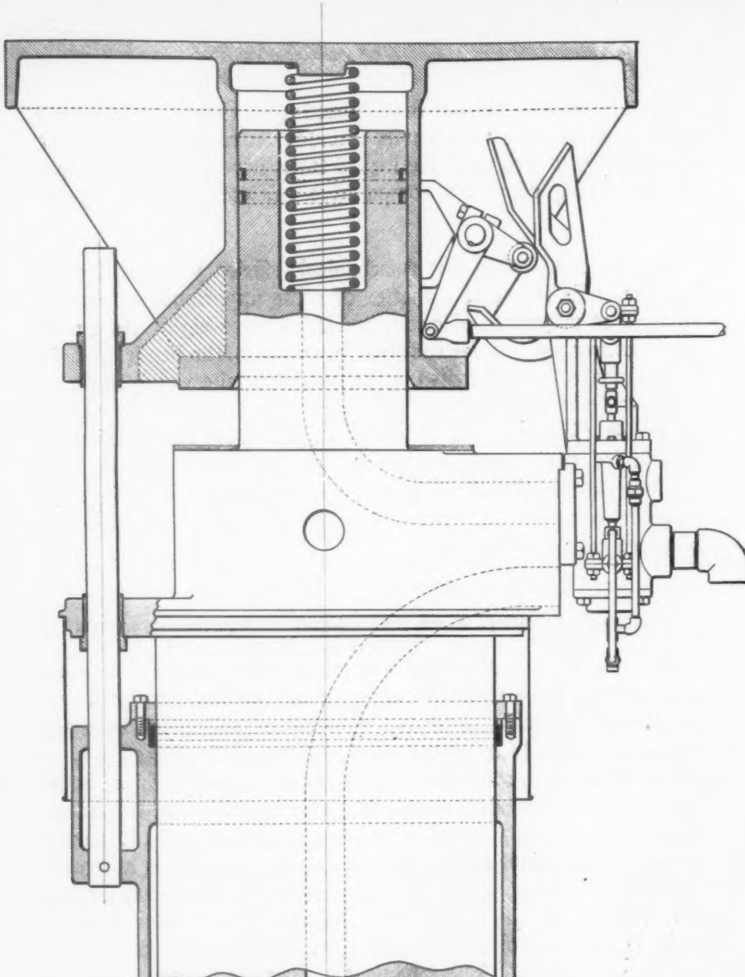

FIG. 2

the anvil cylinder, this upward velocity of the anvil is augmented, and the falling velocity of the table is somewhat retarded, but in any case the momentum of the rising anvil is substantially equal to that of the falling table at the instant of impact, and as a result both table and anvil come to rest with great jarring or ramming effect upon the sand, but without shock or jar upon the foundation or any surrounding material.

26. When the air from the jarring cylinder is discharged at once into the atmosphere the momentum of the falling table may somewhat exceed that of the rising anvil at the instant of impact, but when this air is expanded into the anvil cylinder, it compensates more or less for the loss of spring pressure, as the anvil rises, and in this case the momentum of the rising anvil may exceed that of the falling table at the instant of impact. The difference, however, need not be very pronounced, and it simply results in a slight initial velocity of the table and anvil at the beginning of the next stroke.

27. The advantage of the second expansion is twofold: it utilizes the potential energy of the compressed air in augmenting the momentum of the anvil and at the same time it checks the acceleration of the table due to gravity, and holds it in contact with the load upon it while falling. Otherwise a poorly fitted pattern board or flask may tend to spring away from its support while falling, and cause lost motion productive of a bad mold. For the same purpose, when the air is discharged directly from the jarring cylinder, a long compression spring between the jarring cylinder and its plunger may be introduced with good effect. In several instances such springs as shown in Fig. 2 have been made to carry half the weight of the table with 8 inches compression. They assist in lifting the loaded table and retard its acceleration in falling, and by their use the lifting capacity of jarring tables may be considerably augmented. Their chief purpose, however, is to retard the falling table and hold the pattern flask and sand firmly against it in readiness for the coming blow. With such a spring, the action of the table is, of course, somewhat slower in falling and more stroke is required to produce a given velocity of impact. On the other hand, the table rises faster and runs further to produce a given blow and the increased stroke

reduces the percentage of clearance space to plunger displacement. The spring in this position has, therefore, some beneficial effect upon the consumption of power, while serving a much better purpose in the production of good molds, and although this spring is not so important when the air from the jarring cylinder passes through the anvil cylinder, it may still be of some value in that case also.

28. The valve mechanism and the means by which it is controlled do not particularly concern the present discussion, and it will suffice to say that the machine is started and stopped by an operating lever which controls the admission of air to the automatic mechanism. So long as this lever is held down, the machine will run automatically, and when released the machine will stop. A latched lever is arranged to adjust the stroke, which can be varied while the machine is running. A safety stop is also provided to limit the table movement through the action of the main valve attached to the plunger base. When pressure is admitted to the jarring cylinder, the anvil cylinder opens to exhaust, and while in action the latter descends while the table is rising, and then rises to meet the falling table.

29. Fig. 3 represents the design of a machine now being built for a large foundry to handle half molds weighing 25 tons. The table is a steel casting 8 ft. × 12 ft. with lifting cylinder 3 ft. diameter, and the plunger base forming the anvil is a solid iron casting weighing 65,000 lbs. This is carried upon twenty-two steel springs designed to compress 8 inches under the maximum load and develop a working stress of only 60,000 lbs. per square inch, which is very much less than the usual working stresses on railway car springs and quite within safe limits. The total weight of the machine complete will probably be in excess of 90,000 lbs., and this is carried in a concrete pit designed simply to protect the machine and support the static load on the floor of the pit.

30. The earthquake from a loaded table weighing 65,000 lbs. dropping 2 or 3 inches upon an anvil bedded in the ground can readily be imagined. Not only would it undo the work done by the machine, but a large area of valuable floor space in its vicinity would become useless, and office buildings at a

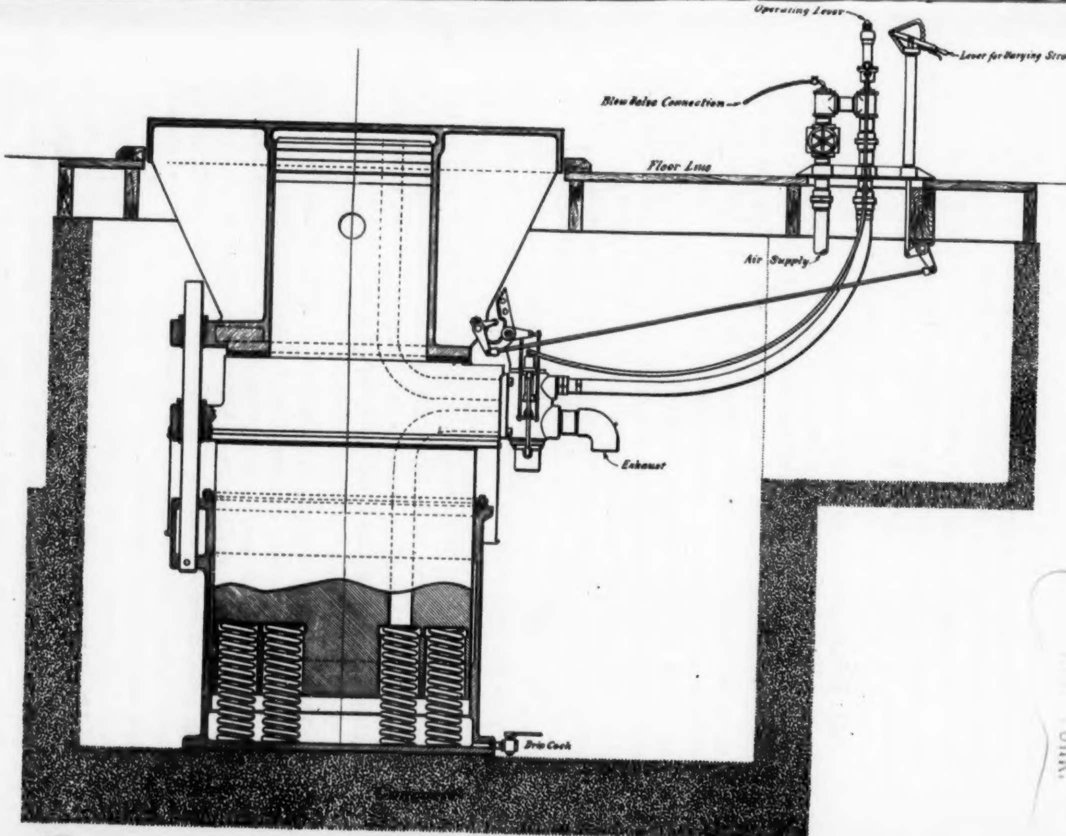
Operating Lever
Lever for Varying Stroke
Blow Valve Connection
Floor Line
Air Supply
Exhaust
Drip Cock

FIG. 3

considerable distance might vibrate in sympathy, while the occupants demanded a cessation of hostilities. In this instance, a comparatively small jarring machine, of a well-known type, with anvil mounted on wooden cribbing had caused more or less annoyance to the occupants of office buildings in the neighborhood, and the machine above described was designed to avoid any further trouble of the same character.

31. It has been shown that a floating anvil which does not rise to meet the falling table, when equal in weight to the latter, has only one-quarter the efficiency of an anvil founded on rock, and the efficiency of such an anvil, when mounted and actuated so as to acquire a momentum equal to that of the falling table at the instant of impact, remains to be determined. Obviously, the anvil will meet the table midway when the latter has fallen half the distance by which they were separated. In terms of the velocity of the table falling the whole distance, its velocity at this point will be $\sqrt{1/2}$ and the velocity of the anvil will be the same. But in this case the velocity of the table is entirely destroyed, while in the previous assumption the change in velocity at the instant of impact was only half the final velocity. The relative changes in velocity are therefore, as $\sqrt{1/2}$ to $1/2$ and the ramming effects in the two cases will be to each other as the square of $\sqrt{1/2}$ to the square of $1/2$ or as $1/2$ to $1/4$. Under the assumed conditions the anvil in the Shockless machine is, therefore, twice as efficient as the same anvil cushioned on a wooden crib.

32. It might be shown still further that the vibratory action which develops equal momentums between the table and anvil is more efficient mechanically than any other action which develops unequal momentums. With compressed air as a working fluid, it pays, however, to utilize its potential energy in the anvil cylinder rather than throw it away, and a decided gain in effect is realized in this way.

33. It may also be pointed out that when the sand is soft the change in the velocity of the table at the instant of impact is greater than it is when rammed, because in the first condition the table movement is arrested before that of the sand, while in the latter condition both stop together.

34. The loss of power in cylinder clearances is well known, and the obvious remedy in a short passage from the valve to the cylinder has led to the use of internal valves of more or less ingenuity and efficiency, but experience in machine design clearly points to the futility of attempting the embodiment of all advantages or the complete elimination of disadvantages in any construction. The best machine for any purpose is the best compromise that can be made between conflicting advantages, and rather than save air by the use of a valve which is comparatively inaccessible, is it not better to sacrifice a little air for the sake of good construction and accessibility to all working parts? At the same time, it may be said that the air consumed in the clearance passage to the jarring cylinder is not wholly wasted. It adds materially to the work done by expansion in the jarring cylinder, and again when discharged into the anvil cylinder, it adds to the momentum of the anvil. In addition to the consumption of air for any given stroke it must not be forgotten that the blow struck in the Shockless machine is twice as effective as the blow for the same expenditure of power on the usual type of jarring machine.

SPECIAL ADAPTABILITY IN HIGH BUILDINGS

35. Attention should also be called to the possibility of installing a machine of the Shockless type on the upper floors of high buildings where many foundries are now being located. The action of the machine is entirely free from jar except where it is wanted on the work produced and the pulsating variation in floor load while running is no greater than is usually experienced in the operation of power squeezers. A number of these machines are now under construction for installation on upper floors, and in this connection it may be of interest to note that the original experimental machine as shown by the photograph Fig. 1 was set up on floor beams over a pit and operated without any vibration appreciable to a man standing on the beams while ramming up a half mold weighing about 1,000 lbs. In this case, the weight of the machine was about 6,000 lbs. and a stroke of 4 inches was employed. The movement of the anvil was about 1 inch, and consequently it met the table when it had fallen about 3 inches. The variation in the load on the floor beams was about

10 per cent. of the static load carried or between 600 and 700 lbs. This variation, however, was gradual, rising and falling with the movement of the table, and when impact occurred the load on the floor beams simply ceased to decrease, and began again to increase without transmitting to the floor beams any part of the shock of impact, which was confined exclusively to the jarring table and its plunger base.

President Waterfall. "Mr. Lewis' paper is now open for discussion."

DISCUSSION

Secretary Moldenke read a discussion sent in by Mr. Alex. E. Outerbridge, of Philadelphia, as follows:

Mr. Outerbridge. "The 'Shockless' Jarring Machine is not only novel in principle and apparently practical in application, but it marks a distinct and important step in advance in the already remarkable development of molding machines in recent years. The value of this improvement will become more and more apparent with the increase in size and capacity of the machine, for the jarring principle is undoubtedly the method *par excellence* for large work.

"The chief objection heretofore, has been caused by ground waves due to shock. Granted that this trouble may now be eliminated, without loss of ramming power and proper flow of sand, by means of the floating anvil, there is apparently almost no limit to the future development of the molding machine. Even to-day quite large and important castings are being successfully made on jarring machines, that a few years ago would have been considered entirely beyond the capacity of any molding machine.

"In the foundry with which the writer is connected, a jarring machine negotiates flasks 80″ × 70″ × 40″ deep in the drag and 16″ deep in the cope. The live heads for

several large and powerful lathes have been made on this machine in this flask, which contained 120 cubic feet of sand, the weight of the sand and flask being 16,800 pounds. The weight of the casting is about 9,000 pounds. Machine uprights have also been made on this machine in flasks 140" × 50" × 38" deep in the drag and 10" deep in the cope. This flask contains 129 cubic feet of sand: the sand and flask together weigh 20,640 pounds. These castings, being of comparatively thin section, weigh about 4,500 pounds each.

"Apart from the reduction in cost of molding these large castings on the jarring machine there is a great advantage in the more uniform weight of duplicate castings and in the more uniform distribution of the sand, the absence of 'spongy spots' and 'hard spots,' inseparable from hand ramming, tending to insure good castings.

"The chief, if not the only objection, to the operation of this machine in the foundry is the 'earthquake' tending to cause sand to drop in contiguous molds in the floor, and in order to overcome this, arrangements are now being made to adapt the shockless principle to the jarring machines already installed. When this has been accomplished it is believed that green sand molds with large overhanging portions can be safely made in the floor alongside of the shockless jarring machine.

"The writer was present at a recent test of a combination rollover jarring machine, and saw a deep pattern rammed up in a flask 23" x 32" x 13" deep, weighing about 1,000 pounds, on the third floor of an old building, without any perceptible shock, and with no more pulsation in the floor than might be expected from the action of an ordinary squeezer."

James A. Murphy. "I want to say that I am also a jarring machine enthusiast and believe that it is one of the greatest labor saving devices that has ever entered the foundry, reducing the time in molding operations. I have never seen one that was used entirely satisfactory. While this one of Mr. Lewis' seems to be a real mechanical job there are

a lot who do not understand it, myself included, and I feel that any discussion bringing out its points might be beneficial to the foundrymen. I am somewhat of a crank and I want to ask Mr. Lewis some questions. If I understand the principle of the shockless jarring machine rightly, the anvil goes down two inches, which relieves the jar given by the opposing force and this holds good with a one-ton, two-ton, or three-ton job for the same machine. In that case would you arrange the anvil so that its resistance would be equal to the opposing force? I mention one, two, or three tons as it is considered the range of weight to be put upon any jarring machine, for any man who is running a jobbing foundry cannot afford to have a machine for every sized job. He wants a machine that will carry across the range of his business. It is not a question of how much work the jarring machine will do but what kind of work you can get from it."

Mr. Lewis. "As I stated in the paper the highest efficiency in jarring machines that could be expected is of one founded upon rock. The efficiency depends upon the weight of the anvil, the heavier the anvil the better, but you all understand the fact that weight costs money and you pay what you please for the efficiency that you desire. Increase in efficiency requires more weight in the anvil and costs more money. In the application of the anvil principle to the shockless machine the anvil rises as the table falls and the momentum of the anvil and the table are equal when they strike, because they are both impelled by the same force. In the same length of time they acquire the same momentum. One discharges energy upon the other. If the weight of the table is three ton and the weight of the anvil is three tons, the two will move together the same distance. If they are separated four inches the anvil will rise two inches and the table drop two inches. If the weight of the table is one ton and that of the anvil is three tons the anvil will rise one inch while the table drops three inches.

"The effect is the same in dropping three inches as though it landed upon an anvil founded on rock. The air consumption is not a very important matter, because the compacting

of the sand by the jarring process is not found very efficient as the process approaches completion, when very little ramming effect is had upon the sand. The drop of the table should vary according to the depth of sand and the density desired."

Mr. Murphy. "I am not entirely satisfied with one thing Mr. Lewis said, *i. e.*, that both the anvil going up and the table coming down were impelled by the same force. That might be the case with a certain regular job, but the machines are built for irregular jobs, and the springs would have the same supporting power all the time. For instance if your springs were built to hold up a one-ton job and you put on the same machine a two-ton job, you would increase your pressure and your springs would have to go down more while your table would come up."

Mr. Lewis. "Well, then the anvil rises faster because there is more stored up energy in the springs. The two momentums are equal and the anvil is rising to meet the table when contact takes place. If the anvil was to wait for the table to drop then of course the springs would go down immediately when it was struck, and the effect of the blow struck would be considerably reduced."

Mr. E. H. Mumford. "Mr. Lewis presented this paper at Atlantic City a week or two ago, and being limited for time I present the same discussion which I suppose is applicable here. Mr. Lewis has said some things with which I do not agree, and which I do not think are warranted by the facts, and it seems to me that I am entitled to a reply.

"This admirably clear exposition of a most ingenious machine contains some assumptions as to other people's machines and a theory of the action of jolt ramming machines upon sand which are disputable.

"Mr. Lewis' reference to tables of many hundreds of successfully working machines as 'flimsy' because they do not happen to be designed according to his patent disclosure, is unworthy of an engineer who knows that the vast majority

of jolt ramming machines in successful service do not resemble his in table design. Other designers would avoid the large percentage of unnecessary weight and destructive shock involved in making the table carry the heavy stiffening which it needs only at the instant of impact and in other machines receives and supports it on an ample surface at the only time it needs support.

"In his broad statement of the minute or less required to jolt-ram a mold in which he ignores the depth of the mold as a condition exacting time varying with the depth for the density of the sand below to gradually reach the top, as also in speaking of the effect of anvil recoil, and in his statement that the longer the stroke the greater is the efficiency, Mr. Lewis treats the compacting of sand by jolt ramming machines as occurring uniformly and simultaneously throughout the mass.

"I refer to the process, and not the result, for, although, in the finished mold there is a comparatively slight difference in density at top and bottom, a much greater difference exists during the early stages of the ramming and has to be taken account of in anvil and drop conditions.

"Last October before the Philadelphia Foundrymen's Association, I called attention to the fact that a zone of proper mold density rises gradually from approximately horizontal joint and pattern surfaces until it nearly reaches the top. Practically as well as theoretically it never does reach the actual top in the time in which the rest of the mold becomes hard enough; and the extreme upper layer must be hand-rammed unless excess sand is used and struck off, in which case the unrammed upper layer is in this excess.

"Were this not true, the many experiments which have been made in ramming molds by dropping sand in cartridges would have borne fruit. If it were true, as Mr. Lewis says, that 'The longer the stroke the greater the efficiency' then a single long stroke of $30 \times 2\frac{1}{2}'' = 6'\ 3''$ should ram a mold better than 30 strokes of $2\frac{1}{2}''$ each.

"The fact that such a long, and according to him, efficient stroke, does not ram a mold except in its lower regions, although Mr. Lewis says it should, seems to show that he thinks of jolt ramming as affecting all parts of the mold simultaneously although the lower layers may be squeezed a little harder by the superincumbent sand.

"Apparently he has not discovered, as I have, that a single fall of many times this height will not compact the upper regions of a relatively deep mold, for the simple reason that the lower regions have not been set by previous blows to a rigidity able to transmit the anvil effect. In other words, only the lowest sand gets the effect of a quick stop or high rate of change in velocity, while the uppermost sand lands so gently on the partly rammed sand below as to confute the hypothesis that ramming proceeds uniformly at all depths.

"Mr. Lewis gives the reason for this behavior of the sand in his statement 'the greater the change in velocity at the moment of impact the greater the ramming effect.' Now, in all the upper regions of the mold, where the sand has considerable depth, the rate of 'change in velocity at the instant of impact' is practically *nil*, nor does it become considerable until the sand below has been brought to a density sufficient to effectively transmit the impact on the anvil to the sand above.

"For this reason, I believe, and have so stated, that the jolt ramming of sand is a progressive process in which the first impact rams the sand next the rigid horizontal planes to the maximum density possible for the machine, matchboard and patterns used, the next impact affecting the sand immediately above *through the medium of the sand already rammed* and so on to the top of the mold in gradually diminishing density. In other words, the inequality of the density of the sand at bottom and top of the mold, practically infinite at the first impact, because then the sand at the top is practically wholly unrammed, and therefore of zero density, diminishes as the zone of hard sand rises toward the top. This has nothing to do with the comparative densities of rammed and

unrammed sand, but has to do with rammed densities. Relatively, unrammed sand has none. This, I think must be evident. So far as the effect of jolt ramming is concerned, unrammed sand is zero in density and sand rammed at all is infinitely dense in comparison.

"This analysis is the only one which can follow the law which Mr. Lewis somewhat crudely states in the above quotation in which he uses the expression 'the change in velocity at the instant of impact.' I think Mr. Lewis will agree with me that no change in the velocity of a body *at the instant* of impact is finitely possible, and that what he intended to say was 'the rate of change in velocity at the instant of impact.'

"So much for the theory of Jolt Ramming. Now to dispute some statements of fact and assumptions as to other machines.

"First let me say that in the abridged history of machine molding given, no mention is made of the stripping plate, without which the art never has been nor ever can be complete. Even Hayden, who, so far as we know, first used a vibrator on a molding machine, would not so exalt his application of a tool even then well-known.

"At the very outset of his paper, Mr. Lewis assumes that foundrymen have only 'hitherto attempted to ram sand by the jarring process.' This is a false assumption, for jolt ramming of sand has been perfectly done for twenty years, and numbers of machines good for 15 tons on the table have been in successful use for several years.

"Mr. Lewis defines jolt ramming machines as 'capable of ramming any mold large or small in a minute or less time.' This would lead to a mistaken idea that the size, or rather the depth, of a mold is immaterial to a machine of given capacity. One of our 16-inch machines which rams a 10-inch barred green sand cope with 20 blows in 10 seconds requires a minute

and a half to ram an ingot mold core 6 feet deep with 190 blows.

"Reference is made to pattern drawing machines and such machines as Mr. Lewis advocates require that the patterns should be attached to the machine, which simple jolt ramming machines do not. Pattern drawing machines as adjuncts to jolt ramming machines do not save time, for they exact separate transportation of flasks and sand between the machine and molding floor, otherwise unnecessary. A recent description of one of these combination machines, costing over $2,000, gave its output, for advertising purposes too, as 50 truck wheel centers from 4 men in 10 hours. A plain jolt machine costing $900 (and a $600 machine would be big enough for the job), with three men has made from 40 to 55 in the same time for the past four years—patterns 'brutally' drawn, as Mr. Lewis says—no pattern drawing machine at all. Wheel centers are not hard to draw.

"Money should not be spent for heavy stationary power machines to roll molds and draw patterns. Money is wasted on a machine to roll a mold by power when a crane will pick up any mold by flask trunnions, on which it has practically rolled itself by the time it is set down where it is wanted. All that is then needed is a pattern guide, and a simple modification of the time-honored 'steadypin' gives that in 99 cases out of a 100.

"In paragraph 12, Mr. Lewis does all the work except the crane work, which he does not mention, on 16 molds 45″ × 60″ × 36″ (such a mold might weigh 5,500 lbs.), in eight hours, and he thus offers a good illustration of overlooking the great question of lifting and carrying in connection with the jolt ramming of large molds. There are 64 lifts and carries to be made on this job, and every minute on a hitch, lift and carry is an hour on the job. So any foundryman can judge in how far from the eight hours named by Mr. Lewis it is possible to make and finish 16 molds 3′9″ × 5′ 0″ × 3′0″ deep with only the help necessary to perform only the operations he describes in his schedule.

"I think Mr. Lewis exaggerates the damage done by shock or jarring of the foundry floor by jolt ramming machines. Of ccurse a great deal depends upon the nature of the work near the machine.

"In congested localities in cities, where heavy machinery such as steam hammers is objectionable to the neighborhood, a machine such as Mr. Lewis' 'Shockless' finds a unique fitness.

"Heavy hanging green sand cores should not be placed near jolt ramming operations, especially on swampy ground, but abundant testimony is to be had that the simpler form of machine is no such Ætna Shaking Pluto as Mr. Lewis claims. I have in fact been so doubtful of there being a market for the more expensive and complicated machine that I have as yet done nothing with a 'shockless', patent on which I applied for last September.

"Meantime we have put in service in a large foundry a 32″ plain machine which, with 100 lbs. air service, is ramming half molds weighing 40,000 lbs., and the shock in the foundry is ridiculed by the management, and no office buildings rock.

"Were anvils of other peoples' machine as badly proportioned as Mr. Lewis reports, there might be some excuse for his strictures. But they are not.

"Mr. Lewis assumes that 'the weight of the anvil is generally limited to the weight of the loaded table' and proceeds to develop from this false assumption that the ordinary, 'usual,' jolt ramming machine has only 25% efficiency as compared with one having an anvil of infinite weight, or bedded on rock. Fortunately for the art, anvils in use are quite commonly three times and sometimes seven times the weight of maximum loaded table; which means that anvils are from six to at least ten times the weight of average loaded tables. (One builder only has followed the

bad practice of placing timber crib on top of the concrete.) What this means follows:

Ratio Anvil to Loaded Table	Efficiency of Machine Per Cent	Remarks
Anvil equals loaded table	25	Mr. Lewis' assumption load
" twice " "	44	Min. practice under max. load
" 3 times " "	55	Usual practice under max. load
" 6 " " "	73	Occasional practice under max. load
" 7 " " "	77	Usual practice under average load
" 10 " " "	81	Occasional practice under average load

"So it is seen that Mr. Lewis claims that current practice in jolt ramming wastes from two to three times as much as in fact it does.

"At the Philadelphia meeting above referred to, I stated a simple law of action for jolt machines. I said that the effect of the blow varied directly as the height of the fall and inversely as the deflection of the anvil.

"Mr. Lewis' 'Shockless' to which he refers in paragraph 31 as having 50% efficiency compared with a machine having an infinite anvil, has an anvil of comparatively trivial mass, but doing the work of an anvil of infinite mass by stopping his falling table 'dead' at impact.

"Had his table fallen the same distance and hit an anvil on rock the effect would have been the same.

"But, though he does not put it that way, in order to get that effect without disclosing a monstrous anvil, he pro-

duces a separation and return of anvil and table of perhaps twice this fall, and therefore taking twice the air necessary for the same blow on rock, and gets an efficiency of —— 50%!

"This compares well with the 25% which Mr. Lewis derived for other people's machines, but does not look so well beside the 55% to 81% which belongs to them.

"Now let me raise the question of mechanism.

"In the first place it is to be remembered that a machine which is mechanically fit for machine shop or even smith shop use may be a failure in the foundry.

"Dry sharp sand is omnipresent. It floods the roof structure. It sticks to the windows. The men eat it and breathe it. It might be thought that in a closed pit under a machine the flying, cutting, erosive dust would not prevail. But the pit is not closed. There is an inevitable fissure around the table of the machine through which during its operation a steady shower of sand falls in a thin sheet to the bottom of the pit. In the case of the Tabor Machine, described in this paper, this fall is fully 12 feet in the presence of a surging up and down blast through the floor openings produced by the pulsations of the table and a hurricane of dust if the exhaust is open to the pit as Mr. Lewis shows it.

"Under these circumstances, the exceptional protection afforded the single working plunger of one of our machines is not too good.

"But what will be said of the upturned open, working joint of this subterranean cylinder in the 'Shockless' machine? and, in the bottom of this cup, in water and intruding sand, under a dancing mass of 37 tons (loaded, 62 tons or more) 22 springs!

"Springs, like men, are temperamental, and we all know how some lazy springs in a group will shift the load to abler partners and let their side sag.

"Mr. Lewis has provided a 'drip cock' to let the water out of the bottom of his spring box and shallow cylinder guiding 65,000 lbs. What will he do with the sand? Is exhaust pressure in this cylinder supposed to keep the sand out? Experience with lubricated or wet plunger fits exposed to sand is that air gets out while sand gets in—always.

"Still another foundry condition militates against the commercial success of this machine. Not one load in a hundred placed by a crane on the table of a jolt ramming machine is balanced over the plunger. Jolt ramming plungers of all machines are suffering from eccentric loading.

"The centers of gravity of sand molds are rarely in the vertical center lines of the flasks; and it is practically impossible to balance them on the machine tables by the eye. In a machine of the magnitude of this Tabor machine the plunger-jamming, plunger-wearing moment may amount to many thousand foot-pounds. It is easy to secure balanced loading of these tables, but Mr. Lewis seems to have overlooked it, for it calls for mechanical provision he does not show nor mention.

"There is another principle in jolt ramming machine anvils which the centering of molds affects materially and the 'floating anvil' of the Tabor machine is peculiarly sensitive to it; for its very existence as an anvil, or more particularly the existence of the comparatively frail cup and springs on which it rides with fury, depends upon central impact.

"In order that the ramming impact in any jolt ramming machine may be according to mechanical law and not disorganize mechanism, the center of gravity of the loaded table and the center of gravity of the anvil must be in the same vertical line.

"No one knows better than Mr. Lewis that eccentric impact is mainly responsible for broken hammer rods, and that the guiding of the tup close down to the anvil and the supersession of the Morrisson hammer with its massive rod

by this guided type with slender rod was due to the impracticability of keeping hammer impacts central.

"It is easily practicable to keep jolt ramming impacts central, and I believe it vital to any so called 'shockless' machines in which, as in this Tabor machine, and as in steam hammers, the heavy deflecting shocks of eccentric impact are delivered to mechanism instead of to terra firma.

"Let me illustrate the material reality of this eccentricity in foundry practice.

"Take a cheek mold for a locomotive cylinder, and assume that it is 6′ x 8′ on the joint and 4′ deep. The pattern for the saddle would occupy 40% of the upper half of such a flask if it were a complete prism as it would be in a foundry making cylinders only now and then. 6,000 lbs. of sand 2′ from the center of such a flask would represent a static moment of 12,000 foot pounds, and in the final impacts, when the sand has become practically rigid and impact, is practically $\frac{MV^2}{2}$, this tendency to rotate horizontally a 'floating' anvil, measured in foot-pounds would be, for a fall of 3″ and a velocity of 4′ per second, 6,000 foot-pounds—a very considerable force to be absorbed by a cast iron cylinder one hundred and twenty times a minute.

"Springs, volatile, elastic, yielding—the most unreliable, uncertain and unwelcome members of mechanical society—seem peripatetic among Mr. Lewis' genii. In Fig. 2 he shows a spring in the attic as well as the 22 in the cellar. He says of this spring that its 'chief purpose (however) is to retard the falling table and hold the pattern, flask, and sand firmly against it in readiness for the coming blow.'

"But every other designer of jolt-ramming machines finds an absolutely reliable plunger compression or preadmission a far more satisfactory agent for controlling table

stability, while practically all the energy absorbed in this air spring is immediately utilized for the next blow.

"Since the above was written, three exact duplicates of the 40,000 lb. simple jolt-ramming machine above mentioned have been ordered by the same good business men and good engineers who installed the first, after careful consideration of the 'shockless.' This sounds like commercialism, and, as such, unwelcome in a technical discussion. But it is not. It is a concise example of the arbitrament of common sense which all of us as engineers must accept."

The President. "It seems to me that the reply to Mr. Lewis' paper has been prepared with a great deal of care, and of course Mr. Lewis will want to reply to it."

Mr. Lewis. "In reply to the discussion which has been given on my paper, I do not propose to take up a great deal of time, because jarring machines of the shockless type, to which I refer, are here on exhibition and speak for themselves. I am grateful for the appreciation expressed, and for any well founded criticisms,. whether favorable or otherwise, which may lead to further improvement, but I object to unwarrantable assumptions as the basis for conclusions which do not apply to the subject in hand.

"I do not propose to argue whether the adjective 'flimsy' applies more pointedly to a light thin wafer of cast iron, which can be easily sprung or peened out of shape, than it does to a deep beam securely braced in all directions, because foundrymen generally have ideas of their own and no lack of adjectives to give them force. I deny, however, that my jarring table is loaded down with excessive weight because of its enormous strength and stiffness. Metal well distributed is used to good advantage, and here again no argument is needed.

"It has been said that I treat the compacting of sand by jolt ramming machines as occurring uniformly and simultaneously throughout the mass, whereas in the second

paragraph of my paper, I say, referring to this method of ramming: 'The sand is rammed as it should be, densest at the surface of the pattern and of decreasing density above, thus favoring the escape of gases when the mold is poured.' I never had any other idea about it, and never met anyone who pretended to think that jar ramming formed a crust on top of a mold while the sand beneath was nice and soft. There is nothing in my paper to indicate in any way that my understanding of the process is at all different from the common understanding of it as set forth by my critic. Nor does the acceptance of this understanding affect my contention that the longer the stroke the greater the efficiency. The ramming effect referred to in my paper is the kinetic energy given out by a change in velocity due to impact, and utilized more or less in compacting the sand.

"The progressive nature of jar ramming from the bottom up, is, I believe, self-evident, but the relative density of different parts of a mold can never be more than the relative weights of different parts per cubic foot and very far from infinite at any time. If it be true, as stated on very good authority in the *Iron Age*, last July, that the density of sand is increased 25 to 30% by running, it can hardly be true as stated now by the same authority that the difference in density of the sand at top and bottom of the mold is practically infinite at the first impact.

"As to the change in velocity of the table at the instant of impact, I mean, of course, the change in velocity during that very minute fraction of a second while the pressure of impact exceeds the static load. I do not mean the *rate* of change in velocity at the instant of impact, because that rate does not hold throughout the duration of contact, and it has very little to do with the final result.

"I am said to assume at the very outset of my paper that foundrymen have only 'hitherto attempted to ram sand by the jarring process,' in answer to which I would refer to the third paragraph, which begins 'Jarring machines have been

in practical use for many years without attracting much attention.'

" 'The records of the patent office go back to 1869,' etc., making further comment on this criticism superfluous. Nor does it refute my estimate of the time needed to ram any mold on a jarring machine to say that some machines require a minute and a half to do what the shockless machine certainly could do in a minute or less time.

"As to the damage done by shock in the foundry floor, a good deal of evidence was presented to this Association a year ago. Mr. Outerbridge has confirmed it in his discussion and many others have had the same experience. Where the shock of steam hammers has to be endured, I do not think it would be worth while to put in a shockless jarring machine, but the choice rests with the user, and in addition to the evidence for the need of a shockless jarring machine already adduced, let me read a paragraph from a letter just received from abroad. 'We are employing in our foundry a jarring machine with a 48" x 60" table, on which we make molds weighing with sand and flask from 1,500 to 2,000 Kos. but our neighbors are complaining of the shocks which are transmitted to the ground and are even damaging our molds when we place the cores.'

"In regard to the weight of anvil being generally limited to the weight of the loaded table, I would say that this conclusion was reached from a number of observations, and confirmed indirectly by the same authority who now disputes it. I am glad to be assured, however, that my estimate is too low, because the greater the weight of anvil or the more the money buried under ground by competitors, the better for the shockless machine, whose uprising anvil is always more efficient than an anvil of double its weight mounted on a wooden crib.

"I know there is some prejudice against the use of springs, founded chiefly upon ignorance of the duty they should be made to perform. I have seen a great many springs

which failed to act as intended and sometines this has been due to the use of wrought iron or brass instead of high carbon spring steel properly tempered, but when good material is employed, I have seldom known a spring to fail except from bad design, and good steel springs within certain well defined limits, I believe, to be as reliable as any other piece of mechanism. The railroads are the largest consumers of spring steel. They specify the working stresses found to be safe and by keeping well within their limits, the uncertainty about the action of steel springs may be dismissed as no greater than that attached to any other element of machine construction.

"Of course, it is important to have the load central on any jarring machine, and since there is no difficulty about locating it in that position, I will not take up your time in considering the effect of eccentric loads. Suffice it to say, therefore, that a reasonable amount of displacement does not appreciably affect the action of the shockless machine as shown by shifting the sand in the flask on the exhibition machine.

"In regard to the effect of sand and dust, I do not pretend to say that these elements are worth much as lubricants for machinery, but I can refer to a table of the type described in my paper which has been in successful operation for more than three years, and I would call attention to the fact that dust cannot work in very rapidly where air under pressure is working its way out. In the machine which exhausts through the anvil cylinder, I prefer to leave the drip cock open or simply use an open pipe through which part of the air and all of the entrained water is continuously passing while the machine is running.

"There is, therefore, less danger from sand and dust in the working of the shockless machine than in other types and I do not believe any of the objections that have been raised will throw dust in the eyes of foundry men who examine my shockless jarring machine.

Mr. Mumford. "I want to say that we have received the identical letter Mr. Lewis read from Belgium, and I have not yet had time to answer it, but when I do answer it I shall certainly recommend Mr. Lewis' machine to the Belgian people."

A Member. "I would like a copy of Mr. Lewis' paper to see how he arrives at his conclusions. If this principle is applicable to shockless jarring machines I don't see why it is not applicable to steam hammers. Steam hammers are all right in the foundry business. Jarring machines are not as bad on foundries as steam hammers, and I don't see much trouble from them. We know that such things happen and they happen on heavy operations of any kind."

Mr. Lewis. "In regard to the application of the principle to a steam hammer, that matter has been considered, but jarring sand is not equivalent to forging steel. Consider, for example, a large heavy forging that takes many men to handle with cranes and porter bars, resting upon a moving anvil. Such work is difficult enough to forge upon a stationary anvil and if the anvil were moving, the difficulty and danger would obviously be increased."

Mr. Anthes. "I have been looking into the jarring core machine that is working on the principle of a ratchet which is turned by hand.

"The ratchet takes the place of the anvil in the ordinary jarring machine and a steam plunger that goes down and engages with the table or ratchet. The inventor of the special core machine told me that in cases of small diameter he increased the speed of this ratchet and made the stroke much shorter, and when he wanted to make a core thicker in diameter, he made the stroke a little longer. Now, is a long stroke a special advantage on a long core? That is a question I would like to have Mr. Mumford or Mr. Lewis explain."

Mr. Mumford. "I will say that I don't believe that on any type of jolt ramming molding machine a long stroke is

particularly advantageous. Strokes may be multiplied for any effect."

Mr. Lewis. "I am not familiar with the core machine referred to, but from an extensive series of experiments that I have made upon the ultimate effect of jar-ramming with different lengths of stroke, I can say very positively that the longer the stroke the greater the possible density of the mold or core. This fact can be easily demonstrated on a shockless jarring machine with variable stroke. Beginning with the shortest stroke, I have rammed a deep mold by giving it several hundred blows until the compacting of the sand appeared to have reached its limit. Then by increasing the length of stroke from 1″ to 4″, I have seen the very next blow reduce the depth of the sand nearly two inches and succeeding blows, would, of course, effect less and less movement as the ultimate density for the greater drop was approached. I am very confident, therefore, that there is an ultimate density for every length of stroke, and when this truth is realized, as it must be by anyone who takes the trouble to investigate, there can be no question whatever as to the truth of my contention that the longer the stroke the greater the efficiency of a jarring machine. Take, for instance the mold above referred to which has been rammed to its ultimate density by 1″ strokes. A hundred more strokes of that length would have no perceptible effect, but one stroke of 4″ would have a very substantial effect. After the ultimate density corresponding to the drop has been reached, all of the power expended is wasted, and nearly all the power used is wasted as this ultimate density is approached. Economy of power clearly points to the use of the longest stroke practicable, while on the other hand, the wear and tear on the machine, flasks and patterns suggest moderation and the adoption of a safe limit within which the stroke can be varied to meet the exigencies of any given case. It is better, I believe, not to begin jarring with a very long stroke on account of the air confined in the sand, which may cut a channel for itself and blow, if the stroke is too long, but after the sand has been well settled, I am very sure the stroke can be lengthened with great economy in power and generally with very good results.

"It should also be observed that continued jarring after the mold has reached the ultimate density due to the stroke not only wastes power but spoils the mold, for as soon as the sand ceases to pack it begins to break up. The success of the process, therefore, depends a good deal upon knowing when to stop, and since good terminal facilities are generally appreciated, I will not take up any more of your time in prolonging this discussion."

Dr. Moldenke. "We will ask Mr. Power, of the Emerson Company, to read the next paper, on 'Reward-Premium or Bonus.' "

Mr. Power. "The few remarks to follow were jotted down by me at the last moment. Individual efficiency has never had as specific a place in foundry work as it has to-day."

REWARD—PREMIUM—BONUS

By W. J. Power, New York City

Discipline, organization, standardization of conditions and operations, are elements of modern business, which while greatly aiding to stimulate and increase productions, inure for the most part to the benefit of the Employer.

They are as essential to progress and success as is the establishment of reward or premium—they are in fact the premises or foundation of the intelligent distribution of premium.

Premium should be the last step undertaken in the betterment of a plant. It is the recognition of a workman's ability—of his willing and active attitude of mind and body—to avail himself of the improved conditions which the above mentioned elements have perfected. Without discipline, organization and standardization, premium or reward will be predicated on a very doubtful base, and will have but a small proportion of its efficacy which would obtain were it based on these cornerstones; and it is equally true that these important elements will be deprived of much of their value unless the workman is the beneficiary of some reward which will induce him to give full play to their helpful influences.

Reward for his effort and for the proper economy of his time in reality starts the worker in a business of his own—it opens for him accounts of profit and loss—it appeals directly to his purse.

Time, the most precious of all earthly gifts, is coined into money or is lost, entirely at the option of the workman.

The tremendous difierence between a man thoroughly interested in earning a reward, planning and scheming to make the reward as great as possible, and a man plodding along on a fixed day or hourly wage, can be appreciated by those only who have daily mingled with each class of men.

It can be positively stated that man or foreman will accomplish two-thirds more work than he will on a fixed day-rate without premium. There are thousands of examples to corroborate this statement.

It can also be shown with certainty, that a workman's development in his craft is much greater under a reward system than under a fixed pay system—that his originality and inventive genius are inspired very considerably more, that his permanence as an employee is enhanced markedly.

Premium in a Foundry

There is perhaps no other craft to which reward for effort can be so appropriately applied as to that of the molder. As a rule his work is one round of physical exertion. The quality and amount of his work are more dependent on mental and muscular ability than on the absolute capacity of a machine or apparatus (conditions existing in many of the other trades).

The result is that in every day rate shop or fixed rate foundry ever visited by the author, a very restful and leisurely gait was noticeable—while a close check of the actual hours showed from 6 to 6½ hours per day.

The payment of premium based on proper standards will bring this amount up to an average of eight hours at a much more intensive gait and with proper inspection will improve the quality of the work done. This statement is also founded on the experiences of the author and of others.

Volumes could be written in elaboration of the advantages of a reward plan of paying labor, when such a plan of reward is

consequent upon the successful operation of the other vital features of management.

The practical results of a co-operative effort between employer and employee, the former paving the road well for the latter, should be at least a net gain in cost to the former of 28% and an increment in earnings of 20% to the latter.

Dr. Moldenke. "There being no discussion on Mr. Power's paper, in the absence of President Waterfall, who was called away for a few minutes for a committee meeting, I beg to call upon Mr. Harrington Emerson to read his brother's paper on 'Rejected Castings in Steel Foundries.' "

Mr. Harrington Emerson. "All progress in the Universe has depended upon running with the tide instead of against it. All forms of life, are in reality adaptations to underlying conditions, principles, natural laws.

"I am not here this morning to advocate or defend any device or method. Underlying all devices and methods are certain principles. These principles are not the property of any one; they belong as much to all the world as do the currents in the air, the water currents, the seasons and warmth which comes to us from the earth and sun. All that Mr. Emerson is attempting to say in his brief paper is that if certain commonsense principles are applied to such a subject as faulty castings in a steel foundry, the number of faulty castings will be reduced, and this effort is economically worth while."

REJECTED CASTINGS IN STEEL FOUNDRIES

By Samuel D. I. Emerson, New York City

The purpose of this paper is to show how the principles of efficiency may be applied with profit to the subject of rejected castings in steel foundries.

High manufacturing efficiency, resulting in minimum unit cost, has of late years received much attention, with the general understanding that new and improved machinery and more strenuous effort, were the means best calculated to bring about the desired result.

Now we are beginning to realize that efficiency means something more, something different from this former conception. The new school defines efficiency as "the elimination of unnecessary wastes," so that with less effort, less power, less machinery, better results may be obtained.

In most manufacturing plants, there are many wastes, waste in power generation and use, waste in machinery installation, waste of materials, large waste of effort and yet larger waste of time.

In foundries, defective or rejected castings constitute an element of loss, which, like the poor, is always with us, so that it may be profitable to consider how the principles of efficiency can be applied to this problem.

Of these principles, that of "Accurate and prompt records," is the most important as it is an absolutely essential prerequisite to the proper application of further principles and methods.

Practical Foundrymen, until within the last few years, did not fully realize the importance of accurate records as to foundry rejections. Inspection was less severe, customers accepted without question the shipments made, the loss due to rejections was an undetermined quantity and generally assumed to be less than it actually was.

Now fortunately, Chartered Accountants, coming to us from England, have revolutionized former methods of cost accounting and have demonstrated the value of accurate detailed records to those who employed them, but the rank and file are still disposed to make but little practical use of the new knowledge, so that in many large steel foundries, the records kept, lack vitality.

In some foundries, records as to rejections are not tabulated, in others, the average percentage of rejections is shown on the monthly statement, in those larger foundries, having a modern accounting department, detailed statements are elaborated and sent to the head office, usually from two to three weeks after the expiration of the working period they cover.

Records handled in this way are of some value from a cost accounting point of view, but as a method of promoting efficiency, as a vital means of reducing loss, they are fairly barren of results.

To ascertain on the 15th of March, that there were 12% rejections on an order completed and shipped on the 20th of February, is not what is meant by "Accurate and prompt records."

The records should be kept and tabulated as to cause, location, number of castings, number of heat, as to each molder or floor gang, with percentage of loss for each working day, or shift and statements made to those responsible for the foundry work within a few hours after the pour, if possible before starting the next day's work.

When a system for obtaining accurate records and placing them in the hands of those in charge of the work has been devised and put in practice, the next step is to make them effective as a means of improvement, which brings us to the application of two further principles of efficiency; (1) Organization and Discipline; (2) Efficiency Rewards.

In those smaller foundries, where it is customary for molders to do all of the work, molding, moving molds, and pouring the metal, where workmen can, with fairness, be paid by the piece, for good castings only, accurate information is well nigh sufficient in order to obtain good results, but in the larger steel foundries, responsibility does not attach to the individual in the same degree; the moulder will object to losing his pay on account of defects for which he may not be responsible. If piece rates are imposed they must be, either on the basis of molds made, without regard to loss, or the rates must be high enough to cover the average of such loss, if charged to the workman. In either case the loss will ultimately be carried by the employer.

In some foundries it will be found productive of good results to bonus foremen on the basis of percentage of rejected castings, paying molding gang on the standard time basis, for molds made. Where the time of the foreman is fully occupied by other duties, a Rejection Department should be organized, with one or more thoroughly competent men, whose sole duty should consist in reducing the percentage of rejections. With an initial low base wage, two-thirds of the pay of these men should be dependent on the results achieved.

Having followed me thus far, the idea may suggest itself to some that I am making considerable outcry for very little wool, but I believe, on the contrary, that the clip will prove considerable.

Many steel foundries have a monthly output of from 3,000 to 5,000 tons of good castings. Most of them have an average loss due to rejected castings of 8 to 9%. The actual money loss varies of course with the cost of materials and labor. The best accountants, with whom I am acquainted, estimate the present

loss on rejections at \$35.00 per ton of 2,000 lbs. I myself prefer to figure it at \$30.00 per ton or \$1.50 per hundred.

With a good output of 5,000 tons per month and 8% rejections, we have a loss of \$13,000.00 per month, not including loss of profits due to reduced output.

Most of the work in connection with this proposed application of efficiency principles to the subject of rejections is already being done in the larger foundries. Rigorous inspection is imposed by contract agreement; considerable clerical work is now devoted to this matter, tabulations are compiled monthly from daily records, etc.

Additions to the clerical force are scarcely needed, at most, one additional clerk for a 5,000 ton foundry.

Assuming that for such a plant it would be necessary to organize a special department with three extra men the cost should not exceed \$600.00 per month, while I am confident, that where rejections now average 8%, they would be reduced by these methods to 5%, the net gain aggregating more than \$50,000.00 per annum.

This assumption is based on practical experience in some of the largest steel foundries in the country.

In a steel foundry where the writer had an opportunity to study conditions thoroughly, we recorded, during a full year's operations, 63 different causes of rejection, many of them, of course, accidental and of infrequent occurrence.

Twelve principal causes were responsible for more than 90% of rejections. 75% were covered by 6 causes. To one cause, "cracks" about 50% of all rejections were attributed.

The records were elaborated as to the 12 principal causes, which at once brought to light some interesting facts.

It had been assumed that cracks were largely due to metallurgical difficulties, but our tables showed them to bear little or no relation to heats, but that they occurred principally as to certain castings, the percentage being very much greater on new work than on orders that had been running for several weeks. From this we concluded that they were mechanically avoidable.

As to a certain casting on which 5 floors had steady work, cracks having averaged for 10 consecutive heats, 17.8%, a careful investigation was made, location of cracks noted on castings, mechanical means taken to eliminate them. Records as to each day's work were given to the three foremen in charge of the floors.

The effect was immediate, in a few days, cracks were reduced to an average of less than 2%, the total of all rejections averaging less than 3% for 30 consecutive heats. The foreman with the best record showed an average of 1.7% total rejections.

One of our 12 principal causes was "Cope Raise" with half of one per cent. rejections charged to it. On investigation it was found that Cope raises were due to loose cross bars in flasks. New bars were gradually substituted; old ones were repaired. At the end of 60 days Cope raises had fallen to an average for the month of less than 1-100 of one per cent.

Second, after cracks came "Dirt in Mold," averaging over 1%. This was run down and found to be most prevalent as to certain molds which were transferred to pouring floor on flat cars. The handling of these cars was given special attention, and "dirt" fell at once to 4th place in our list, with 0.52%.

The records as tabulated revealed enormous differences of percentage of rejections, 1st, as to cause; 2nd, as to castings; 3rd, as to foreman; 4th, as to molding gang.

Rejections under one foreman were more than twice the average of the plant. Under his successor they immediately dropped 50%.

The few examples mentioned indicate in a general way the methods attempted, records were obtained and the work carried on without special organization and without any scheme of bonus to men or foremen as to rejections. The whole subject received only intermittent attention.

At the end of a year's study we reached the following conclusions:

1. In Steel Foundries, rejections are principally due to accidents, or to inefficient methods in core or molding departments.

2. Ninety per cent. of rejections are, mechanically avoidable without reference to metallurgical difficulties.

3. With adequate record, systematic and continual attention, rejections can be reduced to an average of 3%.

4. In order to secure the continual attention required, a separate organization with pay largely dependent on results, is most effective.

Dr. Moldenke. "This is a paper which creates interest because it contains the points that we are up against in daily practice. I would like to have you ask Mr. Emerson some questions."

Mr. Best. "What percentage would Mr. Emerson consider a good average for rejected castings in steel foundry work?"

Mr. Emerson. "It would be impossible for me to answer that question without knowing exactly the character of the castings. A particular study would have to be made of the rejections as they are occurring. This paper holds that it ought to be cut down to 3%. In this particular foundry I think the rejections may be limited to 3%, or in any foundry where the same methods are applied, the rejections should be

down to 3%, but in some steel foundry where the methods may be different it would vary. It is only a question of good practice."

Dr. Moldenke. "Suppose some have 10 to 15 per cent. and even higher, and if they cut down to 3%, it shows something was wrong."

Mr. Emerson. "In this foundry we find a great many rejections occur with change of methods. If you are running along for a week or two, and then make a change in patterns, or if you change from one kind of metal to another, or from one method to another, more rejections occur in a large foundry, and by inspection, seeing the cores are properly placed, and noticing the flaws in them, and if they could be eliminated, the very high percentage of rejections that occasionally occur can be avoided."

Mr. Kennedy. "The question I would ask is probably a little aside from the subject of the paper, but there are other steel foundrymen here, and if some one can answer the question I would be obliged. I know in our own practice that the castings run about a thousand to the ton and we had an average of 2% defective castings in the last two years."

Dr. Moldenke. "Do you make only small castings?"

Mr. Kennedy. "Yes. I am anxious to find out what other people consider a fair allowance for rejected castings."

Dr. Moldenke. "We have a number of steel foundrymen right here; suppose they give us something on the subject."

Mr. Bull. "I congratulate Mr. Kennedy if he has an average of 2%. I believe the average for most foundrymen will come closer to 6%. In our foundry it runs between 2% to 3%, but we have a lot of small castings."

Mr. Wilson. "I have nothing to do with steel, but we have many rejections of castings. It makes a lot of difference where you draw your line as to the percentage of rejected castings. One foundry making the same style may have 4% perhaps, while another will have 3%, and another may have 5% and another 10%, depending upon where the line is drawn."

Mr. Murphy. "I never attached any great importance to the rejection of castings, the reduction from a higher percentage to a lower one only goes to show how much system is employed in the manner of handling it. Some shops show a very much less, than others, and I think it depends much upon shop details. Some people will accept castings that other people will reject. It is easier to reduce the loss in a steel foundry than in an iron foundry, for there are more chances to patch up steel foundry rejections than in an iron foundry."

Dr. Moldenke. "We will next listen to the report of our Committee on Industrial Education, of which Mr. P. Kreuzpointer is chairman."

REPORT OF COMMITTEE ON INDUSTRIAL EDUCATION

By P. Kreuzpointner, Chairman, Altoona, Pa.

Your committee on industrial education takes pleasure in reporting an increasing interest in the educational work of the American Foundrymen's Association, in the United States and even in foreign countries. Your committee has good reason to believe in having gained the good will of the educational authorities whose co-operation is so much desired in solving the problem of industrial education.

This recognition of the work of your committee applies not only to the manner in which its report presented at the Cincinnati convention was received, but also to its other activities during the year. An article, written by your chairman, on "Trade Schools in the Public School System," and published in the *American Machinist* of January 13, 1910, was widely commented on. In this article various reasons were given why the idea of having specific trade education introduced into our public schools would surely fail in its purpose. The traditional organization and machinery of our educational system, as well as the social forces which govern the administration of our schools, are unfavorable to such a venture.

The following extract from a letter of a leading member of the faculty of a University of the Middle West is a sample of the approval with which the article in question was received. "I was very glad to have read what you said in the *American Machinist* on 'Trade Schools in the Public School System.' You are right and I agree with you perfectly. Some day I hope to be able to

show you how well I agree with you by helping to establish a course for preparing teachers, such as you demand in trade school work." An approval of the Cincinnati report by a high educational authority reads as follows: "I have read with great interest the report of the Committee on Industrial Education of the American Foundrymen's Association. It is so sane and suggestive that I wish for it a wide circulation. It is, moreover, entirely in accord with what we are attempting to do in the way of training teachers for industrial work."

January 26th, a request was received from the Ministry of Commerce and Industries of France to send to the Chief of the Bureau all the reports issued by your committee on industrial education and whatever your chairman may have written or spoken on that subject. From the Department of Commerce and Labor at Washington, a request was received to furnish, for official use, the various reports issued from time to time by your committee. These requests were complied with by your chairman with pleasure and dispatch.

In Chicago, last November, a committee on industrial education was established by the Chicago Association of Commerce. This committee issued a pamphlet on the "Industrial and Commercial Education in Relation to Conditions in the City of Chicago." In that pamphlet the committee published fourteen references concerning literature upon the subject of industrial education. In this list of references your committee is honored twice by referring the readers to the Toronto and Cincinnati reports, and the letter by your chairman to superintendent of schools, F. B. Cooper, of Seattle, Washington.

Quotation from the Cincinnati report of your committee may also be found in the pamphlet issued by the American Federation of Labor on "Industrial Education." This pamphlet contains the report of the special committee appointed by the American Federation of Labor to investigate the present industrial educational movement.

Since the participation by labor as well as capital in the movement for industrial education is of importanee, the following paragraphs will be of interest.

"Labor's position regarding the injustice of narrow and prescribed training in selected trades, by both private and public institutions, and the flooding of the labor market with half-trained mechanics for the purpose of exploitation, is perfectly tenable, and the well-founded belief in the viciousness of such practices, and consequent condemnation, is well-nigh unassailable."

"Its advocacy of free schools, free textbooks, and the raising of the compulsory school age has been religiously adhered to, and closely allied to these subjects is that of industrial education, and any serious discussion of the proper kind of vocational training promotes discussion of the former."

"There is a strong reaction coming, in general methods of education, and that growing feeling, which is gaining rapidly in strength, that the human element must be recognized, and cannot be so disregarded as to make the future workers mere automatic machines."

"Experience has shown that the manual training school teachers without actual trade experience do not and cannot successfully solve this great problem, and that progress will necessarily be slow, as new teachers must be provided, a new set of textbooks will have to be written, and the subject taught in a sympathetic and systematic manner. In the last analyses, it is of greater moment to those engaged in industry whether this question should be discussed freely and fairly than it is to mere theorists, who advocate industrial education without having any definite plan or purpose (other than a selfish one) in their advocacy of the same, and it is believed that a unification rather than a multiplication of effort is needed in order to solve this immense problem."

The report speaks with disfavor of the co-operative plan of industrial education (this probably refers to the Fitchburg plan), since it leaves the power how, when and to what extent to educate the boys in a trade too much to the good or ill will of the employer. Thus, while the high school is under obligation to educate all the boys, and the taxpayer is compelled to pay for so doing, yet for one-half of the time their education is subject to the sufferance of the employer. Thus, by the co-operative plan, the committee reasons, the employer has it in his power to give the

boys just as much education as suits his purpose, and the school authorities are not in a position to prevent it, the employer being supposed to know what his needs are. In concluding the report, the committee says: "The inquiries of the committee seem to indicate that, if the American workman is to maintain the high standard of efficiency, the boys and girls of the country must have an opportunity to acquire educated hands and brains, such as may enable them to earn a living in a self-selected vocation, and acquire an intelligent understanding of the duties of good citizenship. No better investment can be made by the taxpayers than to give every youth an opportunity to secure such an education. Such an opportunity is not now within the reach of the great majority of the children of the wage-workers. The present system is inadequate and unsatisfactory."

Reference is further made to the wholesale dropping out of children from the school, owing to lack of interest on the part of the pupils and of the parents, and a dissatisfaction that the schools do not offer instruction of a more practical character. Complaint is also made of the false views and absurd notions which possess the minds of too many of our youth, which cause them to shun work at the trades and to seek the office or store as much more genteel and fitting.

The above extracts have been brought to the attention of the members of the American Foundrymen's Association by your committee because of the fact that there are now three distinct social factors at work, co-operating with each other in one direction and counteracting and crossing each other's paths in other directions. Thus we can easily perceive how, during the progress of the movement for a system of industrial schools and education, the efforts of one of these social forces may be thwarted by the unwilling, if not contrary action of one of the other social forces.

What is the nature of these forces? First, there is the old established educational system of the country with its traditions, its reluctance to change and its isolation from the practical, everyday life of the mass of the people, not to mention the too often

disturbing and retarding social and political influences upon schoolboards, teachers and the schools. This is the available educational force.

Next we encounter the economic force in the urgent necessity for the industries and transportation facilities of the country to be provided with labor of such skill, intelligence and knowledge that the investment of capital may be continued profitably and safely. On the other hand it is essential for the welfare of our country and of all its citizens that we retain our industrial standing among the industrial nations of the world.

The third force in the field for the shaping of a system of industrial education is the workingman himself. This force may be considered the social and humanistic side of industrial education and is chiefly concerned with the physical welfare of the industrial worker.

Here then the question arises, will these three forces work harmoniously together toward the fulfilment of the one aim for which each one is striving, or will these forces run along side by side, like the rails in a track and never meet? In the latter event, something will be accomplished, but it will be inadequate and inefficient, with a great deal of energy and money uselessly wasted in misdirected efforts. It is useless to shut our eyes to the evident probability of this very circumstance to happen.

The teachers, being experts in their pedagogic work and at home in their educational organization, while desirous of contributing their share to the solution of this modern educational problem, seem to assume that this can be done along lines of the old traditional school organization with a little tinkering in methods and curriculum, with the traditional idea still dominating many school-people, that teaching trades has no cultural value and therefore, in order to save our culture and civilization, industrial education must, of necessity, be taught in terms of the cultural or general education of the common and high school. Here the school and teacher come in conflict with the actual and urgent needs of the economic force, represented by capital and the industries, on the one side, and the social force, represented by

labor on the other side. The former, from the very nature of the case and the immediate urgent economic necessity, must have concrete immediate results. The industries and transportation facilities of our great country are not in a condition to wait for the results of our educational system, originally devised to meet the needs of the college, but not the needs of the industrial worker, because these needs did not then exist at all. For the same reason the average mechanic has no confidence in the ability of the professional teacher to meet the practical wants of that kind of industrial education most needed by the industrial worker.

As to the nature of the economic forces which are the main spring underlying our educational efforts, meaning bread and butter to all of us, we have no assurance that at present the industries are doing all that can and ought to be done in proportion to their actual needs. What tentative efforts are being made here and there by the industries are purely local and of necessity more or less experimental. Most of these efforts begin at the top and do not exert any influence in the direction of eventually making the school a preparatory institution for the industrial fabric which it ought to be. They take what mental material is most handy, pick out the best of it and drop the rest, leaving to chance what comes next. It is true that there is ample justification for the present hasty action. Our industries develop and change too rapidly.

Dr. G. Kerschensteiner, the superintendent of schools of the city of Munich, Germany, said in an address to the commercial and industrial interests of that city, "As you see, gentlemen, professional efficiency is here put foremost, because those who cannot stand upon their own feet, vocationally, are unable to help others and prevent them from falling. But in closest contact and intimately related with vocational education must go the second aim of our program; to develop insight into the connections and relations of the interests of all citizens alike and especially of our own country. To take care that this insight manifests itself in the exercise of patriotic self-sacrifice, justice, self-control, cooperative spirit, rational hygiene and sensible frugal habits of living. If we keep the first aim uppermost only in our educational endeavors, then there is danger of training up an exces-

sive professional and individual egotism. A school which devotes all its time to no other than to the sole interest of one's earning capacity, to the desire to gain the greatest possible advantage over others, in the struggle for existence, is no institution to develop civic virtues and patriotic self-abnegation. The power which has been nursed into being, and the disregardful egotism which is consequently developed, is not only injurious to the common weal, but in the end inevitably injures itself." This purely commercial aspect of industrial education creates suspicion among the industrial workers, as if the proposed system of industrial schools was only a scheme to exploit them.

Reviewing the situation in this light we can see how the educational force, the economic force and the social force are liable to nullify each other's best efforts, while all three forces are striving hard, each in its own way, to attain the coveted end. Is there no way to reconcile the conflicting tendencies of these forces? Analyzing the question, it would seem as if we had expected the school and teacher to be the main factor in the solution of the problem. But while the school must eventually take a large share of the responsibility of the educational part of the problem, in the end it is a social-economic question. If we succeed in convincing the parents that industrial education of the broader kind means not only bread and butter but is actually necessary to make work more steady all over the country both for the highly skilled men and the great mass of semi-skilled or so-called monkey-wrench machinists, as well as the unskilled, then we are safe. To accomplish this requires a campaign of education in which employers must lend helping hands. If they succeed in convincing the industrial workers that their anxiety for better trained men is not solely due to a desire for increase of output and dividends, but that these educational efforts are equally necessary for the benefit of the industrial situation, then the social force will be found more willing to co-operate, and the school will join in heartily.

This recognition of the social side of the problem of industrial education by the business men of our country will, of course, require some sacrifices on their part, but they may rest assured that the resulting benefits, directly and indirectly, will amply

justify the outlay in time or money or both. If our poorer European friends and competitors do not hesitate to expend enormous sums for the extension of their splendid system of industrial schools, then our industries may likewise consider such sacrifices as a profitable investment.

What, then, can we do? In considering ways and means how we can make the three powerful forces—the educational force, the economic force, and the social force—harmoniously effective, we do well to keep in mind that our problem in the United States is more difficult of solution on account of the two lost years after children leave school. During these two years they not only learn nothing useful but are apt to forget what little they learned in school. And of the alarmingly great number of young people who thus become stranded educationally, few have a chance to learn a trade. Most of them become narrow specialists, machine hands, or remain unskilled altogether.

As far back as 1731 in the silk industry of Lyons, France, there were counted 90 capitalists, that is, those which furnished raw material and contracts, 800 masters, 8,000 skilled workmen and 41,000 unskilled workers. Grouping those who are dexterously skillful in some particular manipulation of an industry, but are as helpless as an unskilled worker when thrown out of work, with the unskilled, the disproportion between skilled and unskilled is probably greater to-day.

But all these millions of semi-skilled and wholly unskilled industrial workers must contribute their share to the success of our industrial fabric. If they are not possessed of sufficient intelligence to grasp the relation of their work to their own welfare and to the welfare of the community of which they are a part, then in order to keep the industrial machinery going and the community in peace and order, constant supervision and disciplinary measures are required in the shop, and police regulations in the community. This is expensive to the management upon the one side and irritating to the workers upon the other. There is liability of resentment to authority within and without the shop And unless this tendency, which is observable to every thought-

ful person, is counteracted by a judiciously applied industrial education, it is likely to grow.

Who is willing to deny that this process is the natural sequence of the present education and industrial training, which aims chiefly to increase productive capacity; which takes all the intelligence out of the social soil the home and the school has put there, but does nothing to replenish that soil with the elements of fertility for raising more and richer crops of social and industrial intelligence? What right have we under the circumstances to complain that the workingmen are not as intelligent as we would like them to be, not as far-seeing of the complex conditions of modern industrial life, not as submissive to discipline as the modern industrial and social organization demands, not as judicious in the election of their municipal and school-board representatives?

Who has taught them in the past and who is going to teach them in the future these priceless virtues?

This must be the aim of the coming industrial school, and by so doing react favorably upon the home. To this end all men who have the welfare of our country at heart must join in a united effort to devise a system of industrial education which not only develops and increases the productive capacity of the industrial worker, desirable and necessary as this is, but also develops that co-operative spirit which is so beneficial to a community. If industrial education fails to do this it carries with it its own elements of destruction.

Since we are not in a position for some time to come to increase the compulsory education age to sixteen years, the employers ought to unite in establishing a standard of admission to work, which standard the school is to furnish and certify to, on dismissal of the pupils. This would compel the school people to get out of their isolation and to study the educational question not only from the academic standpoint, but also from the social and industrial standpoint. Thus, on the pupils leaving school properly equipped we have to deal with two classes—the one class which cannot or will not go to school any longer. The other class going to school two years more. The former, going to work, ought to be taken care of by an arrangement between the school and the

employer, the latter sending his employees under sixteen years of age to school during a given number of hours during the week, or have them instructed in the shop, if desired. This is where the employer must make sacrifices. Strenuous objections will be made to such a plan, but where there is a will there is a way, and if Cincinnati employers can do it, others ought to be able and willing to do it. Moreover, if they can do it in poorer Germany, where—for instance, in the city of Munich—every employer of whatever kind is compelled to send his employees under eighteen years of age to a school a given number of hours during the week, it ought to be considered a matter of necessity with us to do likewise in the struggle for industrial supremacy, which is growing fiercer every year. No matter how the school is going to provide the necessary preparatory training, the industries must insist upon getting it; and they will get what is needed if no impossibilities are asked, like specific trade education in the public school, which it cannot give. The industries should require of the boy entering their employment fair working knowledge of the three R's, especially of the English language. Of history it is more desirable to have that of foreign countries touched but lightly in the grammar grade, and in teaching the history of the United States emphasis be laid upon the influence of the principal historic events on the development of the social and economic structure and the development of our country rather than memorizing dates of battles. In geography, the location and extent of our natural resources and how the ease or difficulties of transportation and communication in the various parts of the country affect our development. A cursory review of the elementary principles of chemical and physical laws, illustrated in laboratory object lessons in the grammar school, would go farther as a preparation for a better understanding of the physical world and its influence upon life in the coming years of the industrial activity of the pupils.

Here the question arises why it would not be expedient and profitable for the school people to formulate the entrance requirements for boys and girls to enter industrial and civic life, just the same as they now have conferences to formulate the entrance requirements for college. Here is where the manual training people are failing to gain the confidence of the industrial people.

Those of the latter who saw the solution of the industrial education problem in the short cut of the immediate establishment of specific trade schools were disappointed in not getting them in the manual training school, while those who considered that the longer way around was the shortest way home perceived how the manual training annex of the public school was swallowed up by the school traditions, emphasizing the technique of mechanical manipulations by scholastic methods and missing the opportunity of making manual training a living issue in our industrial and social life. Manual training teachers and manual training magazines will have no occasion to complain of criticism and lack of appreciation of their work whenever they succeed in uniting the educational force, the economic force and the social force into one harmonious effort to give us industrial people good training schools for skilled mechanics, and that kind of industrial education for the masses of our industrial workers, skilled and unskilled, which recognizes the intimate relation of the social-economic question with the educational question of industrial education.

Course of Study

To this end the course of study in the shop school, in the school shop, in the two years' preparatory school before sixteen and in the continuation school of the young employees, sent there by the employer at his expense, might embrace the following topics:

English in connection with reading from technical and trade journals on topics of general interest and pertaining to the occupation of the pupils. Geography, co-related questions of the localities where our principal resources are found, the location of our land and water routes. The extent of country covered by our industries and to what extent the physical condition favors or hinders the development of industries and agricultural expansion.

Exercises in composition, using as subjects such historical events or geographical facts or objects of natural history which are closely related with the practical necessities of the pupils. In all this work good penmanship is to be urged. Instruction in natural history should include a review of animal and plant life

and individual animals, plants and minerals which furnish the raw material for the various trades and industries the pupils are engaged in.

Elementary instructions and demonstrations of the properties of bodies, their weight and motions, the nature of the atmosphere, heat, light—magnetism and electricity. The most important phenomena and the use of the laws of nature in the service of mankind. Drawing, freehand and mechanical, should of necessity form an important part of the instruction. The school shop, in order to be thoroughly effective, should be well supplied with machinery and appliances as well as illustrations of interesting subjects relative to the development of our country and to the industries of the locality where the school is located. There should be a museum containing samples of raw materials and specimens of work in its various stages of production. Likewise specimens of work spoiled through carelessness or inefficiency, these specimens to be used as object lessons, weaving in with their use attractive bits of useful information such as would not be comprehended by the pupils if given to them separately and in the abstract. In this way we are able to stimulate the imagination. Because of this lack of imagination, pupils leaving the public school at fourteen, with perhaps a sixth or seventh grade education, soon get weary and tired of any instruction presented to them in a continuous and abstract way. This is the rock the purely academically trained teacher is liable to get wrecked upon whenever he attempts to instruct in a shop or continuation school or evening school.

Even after the age of sixteen great care must be taken not to overstimulate and fatigue the assimilative powers of the young people. The desire for results, both with the teacher and employer, is so great and urgent that there is always danger of forcing the mind, and then there is disappointment. In most cases of that kind it is unjust to blame it upon the unwillingness of the pupils when the real cause is either improper method or lack of preparation. With all this school work there should be a persistent effort to arouse the attention of the young people to the close connection of certain public measures or events taking

place with the welfare of the people and the prosperity of our industries and agriculture.

That a broader conception of the economic and social value of industrial education is already dawning in the minds of progressive men is shown by the fact that your chairman has received three requests, two of them from the heads of State educational institutions, to assist them in the preparation of arguments to show the intimate relation between the industrial educational movement, labor, capital, etc., and the influence of this movement upon our industrial standing and social and economic welfare.

Needless to say that your chairman was only too glad to comply with these requests to the best of his ability. Thus your committee on industrial education has tried, during the year, to faithfully carry out its pleasant mission and to make the American Foundrymen's Association an educational factor in the development of our industries.

In conclusion your committee wishes to thank the members of the Association for their continued confidence.

PAUL KREUZPOINTNER, *Chairman.*

APPENDIX

At the annual meeting of the National Society for the Promotion of Industrial Education, held in Milwaukee, December 2-4, 1909, the following resolutions were adopted:

1. *Resolved,*—That the National Society for the Promotion of Industrial Education at its meeting in Milwaukee respectfully transmit to the President of the United States, to the Vice-President and Chairman of the Senate, to the Speaker of the House of Representatives, and to the Secretary of the Interior and to the United States Commissioner of Education these two reports by a committee of ten members of this Society upon the matter of industrial education.

2. *Resolved,*—That the National Society for the Promotion of Industrial Education commend most earnestly to these high authorities of the Government the importance of this whole matter of industrial education from the standpoint of our national and economic welfare, and urge upon them the duty of an adequate consideration of this subject by those responsible for the national progress. No other factor in modern civilization requires closer study by those who lead the nations of this generation.

3. *Resolved,*—That the National Society for the Promotion of Industrial Education earnestly recommend to the President and to the members of the Senate and the House of Representatives the wisdom of an adequate appropriation to enable the United States Department of Education to undertake such a study as that which is here suggested,

and for that purpose the Society respectfully requests that the President call upon the United States Commissioner of Education for an estimate of such sum as will enable him to undertake and carry through within a reasonable time the study here suggested.

4. *Resolved,*—That the officers of the National Society for the Promotion of Industrial Education are instructed to present these memorials to the high officers of the Government designated above in such form as may seem most fitting.

Dr. Moldenke. "Mr. Kreuzpointer you know is the father of industrial education in this country, and he is known everywhere as the Chairman of our Industrial Education Committee."

Mr. Broughton. "I saw on the programme this particular paper, and have been pleased to listen to the gentleman this morning. The secretary of our company asked me to give it special attention, and I am glad that it touches every phase of the great question.

"Every man should be interested in the result of this work, and I hope that every one of us will take home something from this particular paper. I am very much interested in it for myself. I stayed over Sabbath with an old pastor in Owasso, and he took great delight Monday morning as we went down through one particular street there to show me the exhibit of the work performed by some of the manual training students of the high school. I am sure it was a very creditable work that I saw exhibited.

"Besides, the young man where I visited, was a pupil, and his mother took great delight in taking me into the sitting room and showing me a jardiniere stand the young man had made in school, as it was his first work.

"My experience in this line at home is that our high schools should fit the men for our employment. They want

to use their brain not their muscle. We don't blame them for that, but if their brain is also educated along the line of mechanical ingenuity we have got both, and we have a young man who can fit himself into a situation of using his hands in the construction of something. An educated man from our high schools is a better mechanic because he is educated. I also say that a man who is able to perform manual labor is better learned because he has two channels to draw from. I trust every one will take this matter home and consider it."

Mr. Kreuzpointer. "Mr. Chairman, Watching this development for the last forty years I have found that at the present time what we need in our American young men is mechanical training. I have known hundreds of young men, and I find the average young American boy will in the course of a few months pick up a mechanical trade. We have arrived at a state in our industrial development where underlying essential principles are more necessary. Industrial employers all agree upon the point that these young men will be better trained if they have mechanical ability, if when they come in the shop they know the essential underlying principles that they can get in the school, and henceforth our educational system must be fashioned chiefly to the point that the school will give what the shop cannot give, and the shop give what the school cannot give; then we will be as strong as any other nation in the world."

Mr. Wilkinson. "I don't suppose I can go very deeply into this educational business as our friend here, but it happens that it has come into my home in a very strong way.

"Once upon a time my little son went to work for 75 cents a day, and a certain gentleman some of you know, asked me what my son was going to do. He had had a school education. I said, 'I don't know. Run around, I suppose with the other boys.' He said, 'Bring him down to the works. We will find him something to do.' We got that boy to take an interest in what I worked at myself, and it was not long before he was in one of the manual train-

ing schools, and it was not long before he graduated from an academy or high school, and it won't be long, if he lives —and I hope he may—that he will finish his examinations for a mechanical engineer. He is now being raised for a position he has in view, and he was led to take up mechanical engineering by having been in the manual training school."

Dr. Moldenke. "He has a very good father, gentlemen! His father was my right hand man for about ten years in Pittsburgh. The boy takes after him."

Mr. Estep. "As a father of three boys I want to say the best investment I made was a course my boy took at the shop with tools. One of my boys is a mechanical draftsman for a consulting engineer."

The convention here adjourned until 3 P. M.

FIFTH SESSION.

Thursday, 3 P. M., June 9, 1910.

President Waterfall. "Gentlemen, we begin the afternoon session of the Association of American Foundrymen. We have changed the order of the programme somewhat as we would have to darken the room now and it would waste time to get the light again; so we will start with the latter part of the programme and work back. Dr. Moldenke will read a paper on 'Suggested Specifications for Foundry Coke.'"

SUGGESTED SPECIFICATIONS FOR FOUNDRY COKE

By Dr. R. Moldenke, Watchung, N. J.

The subject of Specifications for Foundry Coke has been long agitated, but very little so far accomplished, and this probably because we have been going through just such a change in practice in our coke as we have in our pig irons ever since more liberal and yet more exact views have prevailed. The appearance of a coke no longer carries the weight it formerly did, and all that is now asked is that it melts iron properly, and has a composition to do this without serious detriment to the metal.

This change in practice has undoubtedly been the result of the educational efforts of the "By-product" coke people, and as it has meant the saving of much money formerly spent in freights, the foundry industry has been the gainer in every direction on the coke item.

There is still much to be learned by the foundryman regarding the fuel he uses for melting purposes. Too often the blame for poor results is placed on the coke, when the real trouble lies in his melting practice. So that there may be no doubt about the fuel end, it is highly advisable that a good and yet liberal set of specifications for foundry coke drawn up so that coke bought under them may assure the foundryman that on this item of his daily work he may be reasonably safe. If then he runs into trouble, he will have eliminated the coke from his study of the difficulty.

There are many points which have a bearing on the value of a coke and yet cannot well be added to such specifications.

Thus, the cellular structure is an important factor on the working of the coke in the cupola. It must be remembered that in contra-distinction to blast furnace practice, where there is a reducing atmosphere, in the cupola it is oxidizing. In the blast furnace the cellular structure of the coke should be as great as possible, so that every molecule of oxygen is used up in burning the carbon, and with an excess of incandescent carbon make carbonic oxide gas. This means that the lighter the coke—consistent with its carrying power—and the more porous, the better.

On the other hand, for foundry purposes, it is desirable that coke be burned with a slight excess of oxygen, as in boiler practice; so that as complete a combustion of the fuel as possible may result. That is the gas should be carbonic acid with but little carbonic oxide. Now this can best be accomplished by presenting smaller surfaces to the passing oxygen. For that reason the smooth surfaces of anthracite, with no cellular structure whatever, give a most excellent fuel for the cupola, though coke can be burned faster.

Considering average coke to be 50% cellular structure, the blast furnace can take care of higher percentages, while the cupola should have them lower. Very light cokes are therefore to be avoided, and rather the denser, heavier ones—provided the weight does not come from an excess of ash—are to be recommended.

On the question of sulphur, we have still something to learn. As between the volatile sulphur and that fixed in the ash of coke, we do not yet know positively why sometimes with the latter we get more into our castings and at other times proportionally less. We know that temperatures and slag conditions have much to do with this, but until we are more certain, a differentiation of the sulphur content of a coke is not yet safe, the idea being that the dangerous portion of the sulphur only need be kept down.

Further, there is no doubt but that we will eventually have

some means of reducing the sulphur in our molten iron before pouring, and then sulphur in coke will lose some of its terrors.

The following suggestions are presented for specifications for foundry coke, and the following acknowledgments are made. The limits in composition and the base analysis are suggested by Mr. A. W. Belden, Coke expert of the U. S. Geological Survey. They are the result of his extended observation with cokes from all the fields of this country. The portion relating to the shatter test comes from the regular practice of the Detroit "Solvay Coke" plant, Mr. Warren S. Blauvelt having kindly sent the writer the specifications on this point.

The subject of premiums for extra good coke as against penalties for running below the mark has long been advocated by the writer as the only fair way of handling the subject. So long as the limit for rejection is placed at a point which will do no injustice to the producer, he will study to get the best results so that he not only gains financially, but also acquires a reputation for it. Penalizing without giving corresponding premiums for special excellence has always been held as against fundamental law, and where the base analysis has been settled upon, and safe physical tests added to the chemical, the results should be good for consumer and producer alike.

The accompanying suggested specifications are presented for discussion herewith, and it is hoped that some progress be made in this important subject.

SUGGESTED SPECIFICATIONS FOR FOUNDRY COKE.

Coke bought under these specifications should be massive, in large pieces, and as free as possible from black ends and cinder.

SAMPLING:—Each car load, or its equivalent, shall be considered as a unit, and sampled by taking from the exposed surface at least one piece for each ton, and so as to fairly represent the shipment. These samples, properly broken down and ground to the fineness of coarse saw-dust, well mixed and dried before analysis, shall be used as a basis for the payment of the shipment. In case of disagreement between buyer and seller, an independent chemist, mutually agreed upon shall be employed to sample and analyze the coke, the cost to be borne by the party at fault.

BASE ANALYSIS:—The following analysis, representing an average grade of foundry coke, capable of being made in any of the districts supplying foundries, shall be considered the BASE, premiums and penalties to be calculated thereon as determined by the analysis on an agreed base price.

Volatile Matter	1.00
Fixed Carbon	85.50
Ash	12.00
Sulphur	1.10

Moisture:—Payment shall be made on shipments on the basis of "dry coke." The weight received shall therefore be corrected by deducting the water contained. (Note:—Coke producers should add sufficient coke to their tonnage shipments to make up for the water included, as shown by their own determinations.)

Volatile Matter:—For every .50, or fraction thereof, above the 1.00 allowed, deduct .. cents from the price. Over 2.50 rejects the shipment, at the option of the purchaser.

Fixed Carbon:—For every 1.00 or fraction thereof, above 85.50 add, and for every 1.00 or fraction thereof below 85.50, deduct . . cents. Below 78.50 rejects the shipment at the option of the purchaser.

Ash:—For every 0.50 or fraction thereof below 12.00, add, and for every 0.50 or fraction thereof above 12.00, deduct . . cents from the price. Above 15.00 rejects the shipment at the option of the purchaser.

Sulphur:—For every 0.10 or fraction thereof below 1.10 add, and for every 0.10 or fraction thereof above, deduct . . cents from the price. Above 1.30 rejects the shipment at the option of the purchaser.

Shatter Test:—On arrival of the shipment, the coke shall be subjected to a shatter test, as described below. The percentage of fine coke thus determined, above 5 per cent. of the coke, shall be deducted from the amount of coke to be paid for (after allowing for the water), and paid at fine coke prices, previously agreed upon. Above 15 per cent. fine coke rejects the shipment at the option of the purchaser. Fine coke shall be coke that passes through a wire screen with square holes two inches in the clear.

The apparatus for making the shatter test should be a box capable of holding at least 100 pounds coke, supported with the bottom six feet above a cast iron plate. The doors on the bottom of the box shall be so hinged and latched that they will swing freely away when opened, and will not impede the fall of the coke. Boards shall be put around the cast iron plate so that no coke may be lost.

A sample of approximately 50 pounds is taken at random from the car, using a one and a quarter inch tine fork, and placed in the box without attempt to arrange it therein. The entire material shall be dropped four times upon the cast iron plate, the small material and the dust being returned with the large coke each time.

After the fourth drop the material is screened as above given, the screen to be in horizontal position, shaken once only, and no attempt made to put the small pieces through specially.

The coke remaining shall be weighed and the percentage of the breeze determined.

If the sum of the weight indicates a loss of over 1%, the test shall be rejected and a new one made.

Rejection by reason of failure to pass the shatter test shall not take place until at least two check tests have been made.

President Waterfall. "I would like to hear from the gentlemen present who are interested in this question by way of discussion."

Dr. Porter. "I know a great deal more about coke from blast furnace standpoint than foundry standpoint. It seems to me this is a very important matter, and I am glad the volatile matter is taken into consideration. It seems to me, however, necessary to specify in what way that volatile matter shall be determined, because I think that people who have laboratories, or probably a large proportion of them, are using the same methods for coke as they are for coal. The standard method gotten up by the American Chemical Society many years ago, almost invariably gave higher results. There are other methods which give correct results that can be used. The shatter test is very interesting to me. It seems to me it determines the breaking tendency of coke nicely, and I suppose it is about as simple a test as can be worked out, although it does sound rather pristine. I would like to know how well this test checks up. That is, if you take 3 or 4 more determinations of the shatter test on the same amount of coke, I would like to know what agreement can be expected."

Mr. Blauvelt. "It would depend upon the sample you take. If you take a sample of 40 pounds out of a 40-ton car load, you may get a sample that has a number of coarse pieces, and the shatter test might give a very large percentage, possibly up to 60%. That is the reason Dr. Moldenke says there should be three shatter tests made.

"Another point is made on premiums and penalties of so many cents a ton. I would suggest that instead of this, it be made on a percentage basis with the price agreed upon. Because so many cents a ton taken at hundreds of tons would be very large, and unreasonably high. I think also the penalty should be on the percentage basis on a price agreed upon rather than so many cents per ton for units above or below the specifications. However, there are difficulties in the practical application of this to the foundry coke business.

"Dr. Moldenke spoke of the cell space or density of the coke, but did not suggest making this a matter of specification. In preparing eleborate specifications is not this density or cell space also an important question?"

Mr. Blauvelt then read the following discussion on the paper in question:

The desirability of establishing standard specifications for foundry coke is unquestioned. The general principle outlined by Dr. Moldenke of establishing a certain standard and then paying a premium or exacting a penalty, according to whether the coke is above or below said standards, and providing certain limits which if exceeded, would result in the absolute rejection of the coke as unfit for foundry use, would appeal to the layman as an eminently fair arrangement.

Unfortunately, however, there are certain difficulties in the practical application of these principles to the foundry coke business. These difficulties should be clearly understood

by both parties before making coke contracts based on such specifications.

Sampling. The securing of fairly representative samples of coke is very difficult; in fact, it is almost impossible for different men working independently to secure samples which will check very closely. Whether made in beehive or retort ovens, those portions of the oven charge which were heated first will generally be higher in ash and lower in volatile matter than those portions which were heated toward the end of the coking period. Unless the coal is pulverized and thoroughly mixed before it is coked, sulphur is likely to be localized, due to the presence of fairly large pieces of pyrites in the coal. Unless these are removed before coking, or pulverized and mixed uniformly through the charge, it is evident that certain samples might show abnormally high sulphur content where the average coke in the shipment contained a very low percentage of sulphur.

Shatter Test. The shatter test is unquestionably of value, but it is quite difficult to secure very accurate check tests, were it practicable to test, say 10 samples from each carload, the average of these 10 tests would be very fairly representative of the shipment. Such careful testing, involving such large quantities of the material, however, is impracticable. Dr. Moldenke's proposed standard for the shatter test, that is, that more than 25% small coke after the regulation drops shall be sufficient to cause the rejection of the shipment, would greatly reduce the coal field area from which coal could be used in making foundry coke; the ultimate result, of course, would be a higher price for foundry coke. By the shatter test as described, foundry coke actually shipped generally tests from 20 to 30% small coke, that is of coke passing through the 2 inch square openings in the screen after the sample has been dropped four times as described.

Cell Space. Dr. Moldenke calls attention to the fact that in foundry coke it is desirable to have a lower percentage of cell space than in blast furnace coke. In preparing elaborate

specifications, is this question of density of sufficient importance to warrant tests for determining cell space?

The proposed plan for penalties or premiums, based upon whether the coke in any shipment is below or above the standard specifications, might cause much friction between buyer and seller, even when both parties are disposed to be entirely fair and reasonable. Misunderstandings might arise due to failure to secure truly representative samples of the shipments on the part of either the buyer or the seller, and both parties would be inclined to insist that their samples were correct and should determine the settlement. Certain of the tests, notably the test for volatile matter are at best only approximate and maybe somewhat affected by the personal equation of the one making the test. In view of these difficulties, it is a question whether it would be practicable to carry out a coke contract using any such standard specifications with the provided penalties and premiums. It would seem practicable, however, to insert in any coke contract certain limits which the coke must not exceed, failure to comply with which would result either in the rejection of the shipment or in the payment of certain agreed penalties. With a contract drawn up in this way, there would be no question of premiums, and with proper care on the part of the shipper, both in making contracts with specifications which he can live up to with the coals available, and in the sorting and loading of the coke, there should never be any occasion for the rejection of a shipment or for claims on account of coke being below the agreed upon specifications.

Mr. Waterfall. "I would like to hear from Mr. Belden."

Mr. Belden. "Mr. President, and gentlemen, I am sorry I did not get here in time to hear all of the paper, which is very interesting indeed.

"Dr. Moldenke took this question up with me as stated in his paper. In going over this we tried to find a chemical

analysis that would be an average of coke that could be taken any where in the country. These results, I understand were taken from the tests that were made by the geological survey, which gave the quality of coals in the United States. From these tests the analysis of coke can be obtained practically any where in the country.

"The question of penalties and bonus is one which has been agitated and one which has been worrying me for a good many years. In theory the more we study the coke business the less we know about it. As representative of the Government, having been in coke work for the last five years I can say that every day I find I know less than I did the day before. You can see that I feel quite a delicacy in making any remarks in regard to this other than general. The question of sampling is one which would probably cause more trouble than anything else. I think any one who has had anything to do with coke will readily realize that is undoubtedly true.

"If the specifications are adopted it is undoubtedly going to be necessary to go further and have a sample taken and analyzed by a third party in case the two parties to the contract disagree, and I find in foundry practice no foundry orders a large stock of coke, and it is usually used direct from the car, and by the time the disagreement comes to a head the coke is all gone so that the third party would have a pretty hard time to find a sample.

"I find when foundrymen buy coke that they are not interested further than the fact that they find the coke that will do the work that they want to do. The question of how much it accomplishes does not seem to worry them very much, because the use of that coke is such a small item in the work. Coke in foundry work as well as the blast furnace is thought of only when something goes wrong. If something goes wrong in blast furnace or foundry practice the superintendent says,—you will excuse my French—'It is the d—d poor dirty coke we have.' Consequently you will see that 98 or 99% of the foundrymen who purchase coke analyze

it only when they have some trouble. I have not been able to find but two men so far that I have talked with, and I have talked with quite a good many, who analyze their coke unless they have some trouble. If it is a question of specifications, if the matter is big enough for the foundry practice, why it will mean that you have got to analyze every car of coke before you use it. Whether the amount of coke used in an ordinary foundry is large enough to undertake to go to that expense is a question that the foundryman himself, of course, will have to decide.

"I will say this, however, that the good fellows who sell coke probably know which of you do analyze the coke. You have not had any trouble in the last two or three years because there has been plenty of coke available, but when you get around to the question of a coke shortage, if your dealer knows that you analyze your coke, you will probably get a better grade of coke than the other fellows who do not analyze. They will get any coke he can find to give them. If for no other reason than the one of getting the same grade of coke right along, it seems to me it is to the interest of foundrymen to see that every car of coke that he gets is analyzed."

Dr. Moldenke. "I notice that no one has talked about the water question—that we are at present paying for water at coke prices."

Mr. T. B. Best. "In practice I find that coke containing 1% of sulphur is not fit for foundry use. Now, if a standard is to be adopted for my practice I prefer it rated down to 0.80 rather than 1%. In steel melting I have noticed that a great deal more sulphur is absorbed than in iron, therefore if we get a high per cent. of sulphur we are most liable to get an abnormally large amount of sulphur absorbed in the metal, thereby getting very inferior results that we should not have. If we had coke 1.1 or more I am sure we would have more trouble."

The Chairman. "I notice Mr. Field in the audience. I should like to hear from him."

Mr. Field. "I am inclined to say that I am afraid that we will get into very deep water on this entire question. The questions which Dr. Moldenke brings up, look practical on the face of them, but it certainly gets back to a very difficult problem to solve. In other words, you and I sign a contract for coke, and we agree to be bound by the weights at the point of shipment. Now, the exact condition of the coke at that point of shipment is what neither you nor I can tell, because we cannot afford to put a man there to find out; if the coke comes to us and we find that it is heavy, and that there is more water in it than should be: 'That's nothing,' they will say, 'the coke was all right; your scales are wrong. You signed a contract agreeing to abide by the scales at the shipping point,' and there you have it.

"In other words, the specifications will necessitate an entire change in the method in contracting and handling our coke, and it will take a year or two years trying to change that basis; and I know, after several sessions and consultations with other agents, that a special contract made on fixed terms is worth more than would be accomplished by a contract that met with these suggested specifications. If you go into the question of moisture you will have to get the contractor to agree to the weights at the point of delivery.

"As far as the volatile matter goes I think it is very well covered. I am a little bit skeptical about the ash proposition for the simple reason that there are certain cokes for certain purposes that show too low in ash, and if there is a top limit, I think for the safety of the foundryman who does not want too low ash, there ought to be a bottom limit.

"This coke proposition is a question of individual requirement largely. The man with the low tuyered cupola must have a certain kind of coke, and the man with high tuyered must have another kind of coke to get the efficiency

out of his cupola. We would find ourselves, with these specifications, in a great deal more trouble than we are now. Now we would buy certain brands, and equip our cupolas to get the best results out of them.

"On the question of sulphur, we can't shut out low suplhur coke if we want to use it. The difference in price between low sulphur coke and high sulphur is very little. I think it would be foolish to save 50 cents on the coke and then spend $1.50 in getting your mixture up by the use of better pig irons in order to take care of the higher sulphur.

"So that it looks to me as though it was more a question of simple contract. We ought not to be bound by specified limitations for the simple reason that we ought to buy our coke guaranteed, and I happen to be in a district where we can do it. As a member of this association, I would say that if we adopt these specifications the first thing that would come up would be, 'here are the specifications of your association, and though we would like to sell you coke under those specifications, the requirements of the association are suc that we would not expect to. I would not like to see th American Foundrymen's Association put their approval on specifications which will allow 1% sulphur coke. Ninety per cent of the coke that is sold is guaranteed below 1% sulphur; no one thinks of buying anything else for the reason that there is plenty of it to be had under 1% sulphur, and if we get coke under these specifications they will have to change our foundry methods to take care of the high sulphur coke.

"We all know that producers can ship coke that will meet our approval and there is no reason to ship out a poorer grade. It looks to me that some method should be adopted so that each foundryman can specify for himself just what he wants. While I do not like to throw cold water on the proposition, I really think this would do more harm than good."

Dr. Moldenke. "I am not asking for an approval of these suggested specifications, but merely a discussion on their merits. We need something that will remedy a thing like this. We make coke contracts under the best arrangements we can, and expect to get a uniformly good grade of coke continuously. Now our coke agent is also agent for twenty other firms all producing coke in the same district. Naturally instead of getting all our coke from one series of ovens drawing from a certain portion of a certain coal vein, we get what happens to be handy when coke shortages are the rule. The results we get in the foundry are in accordance therewith. Hence the universal desire for specifications for foundry coke that may be recognized as standard. I see, however, that we have yet much to learn on the subject, and thank you most heartily for the free and candid discussion."

NOTE.—*By the Secretary.* The subject of specifications for Foundry Coke was gone over again at a meeting of the Coke Committee of the American Society for testing materials and the set suggested above considerably modified. The Secretary of the committee, who is also your Secretary and the author of the paper in question was instructed to get a discussion in writing on the matter, and the circular letter may be of interest to our members. Here it is:

At a recent meeting at Atlantic City, your Secretary presented the results of a discussion at the Detroit Convention of the American Foundrymen's Association, of a paper he had written on the subject of "Foundry Coke Specifications." This paper you have no doubt seen in the Technical Press.

Briefly stated, the object of the paper was to establish a base analysis for Foundry Coke, such that every District producing this grade of coke could fill the requirements readily, getting a bonus for better material, and suffering a penalty for inferiority. Further, it would serve the objects

of Conservation in so far as the finest quality of coal could be spread over more of the inferior varieties, making an average coke sufficiently serviceable for foundry purposes, and lasting many more years than would be the case with present methods.

Included in the specifications suggested were the admirable requirements of the "shatter test" as practiced by the Detroit plant of the Semet-Solvay Company.

Thus the chemical as well as enough of the physical characteristics of coke were accounted for to make the discussion worth while.

The result, however, showed plainly that the Foundry Industry is not ready to accept a lower standard base analysis, so long as the excellent Connellsville Cokes are still available. Also, that it would be best to allow each purchaser to specify his requirements and his rejection points. That Standard Methods for the Analysis of Coke are desirable. That in spite of the difficulty of the "shortage in weight" question all foundrymen are up against, it might be well to work in the direction of payment on the basis of "dry coke," to eliminate the moisture disputes, etc.

The meeting therefore instructed the Secretary to send to the members the suggested set of Specifications (modified from those presented at Detroit,) with request for criticism, as well as a suggestion of the analysis that the district the member lives in might be expected to furnish, so that these analyses can be appended to the specifications ultimately adopted, as a guide for foundrymen.

Mr. Waterfall. "The value of the papers is to bring out discussion. 'Foundry Transportation Methods,' by Mr. David Gaehr, Cleveland, Ohio is next. Mr. Lane will read this paper."

OVERHEAD TROLLEY SYSTEMS FOR THE FOUNDRY

By David Gaehr, Cleveland, O.

INTRODUCTORY.

The title of this paper implies two essential functions in the handling of materials, namely, hoisting and conveying, which are sometimes entirely dependent on each other, sometimes combined to good advantage within certain limitations. Each has received a great deal of abstract treatment in your past conventions.

The scope of this paper is principally to call attention to the advantages of overhead tramrail (or monorail or telpher) systems, and, by comparing these with the relative merits of other systems, it is hoped that exponents of each will contribute to a wholesome discussion for the good of the foundry industry.

The word system applied to a transportation scheme presupposes a careful analysis of the conveying and hoisting requirements, for each individual case, and a solution for each specific set of conditions, worked out in a careful and thorough manner.

Probably all of you have seen installations of this nature which did not work out well, because they were not well designed nor carefully erected, but simply put into place by incompetent men, ignorant of the requirements of a good overhead track. Not many owners of industrial establishments and comparatively few superintendents appreciate the importance of a carefully constructed trolley track, though the operating cost of a first-class installation contrasted with

one of the "good enough" installations is certainly of enough significance to deserve attention.

As a means of conveying the Overhead Trolley System in factories is rivaled by schemes employing *man* as "beast of burden" or as a "carthorse" (in connection with wheelbarrows and trucks having two, three and four wheels and being more or less primitive in design and crude in construction), by *horse-drawn* and *automobile trucks* (the latter using gasoline or electricity or steam for motive power), by *industrial railway systems* (which in their advanced types dispense with the services of man, except for loading and unloading operations and running the locomotive, which may be propelled by steam, compressed air, gasoline or electricity obtained from direct or alternating current lines or from storage batteries,) by *travelling cranes* (which are really the prototype of trolley systems), by *locomotive cranes* (used on industrial railway systems) and by *gantry cranes* (which are really a combination of overhead cranes on industrial railway systems). The last three types of conveying appliances, possessing at the same time the ability to hoist and lower loads, are capable of adapting themselves to as many forms of power as the industrial locomotives.

Of these rivals each has its definite scope which the others cannot invade. Therefore, comparison is to be made of the relative merits only for cases in which a trolley system and one or several of the above can be used.

Taking up these various methods and means of conveying we find that whenever the handling of material has been made the subject of special study, with a view of systematizing the production in the plant and putting it on an economical basis, man's sphere for conveying material should be extremely limited. A strong man ordinarily cannot carry more than 150 pounds and that with difficulty for distances over 150 feet when subject to repetition. With the same expenditure of energy, when not obliged to support the load, he could, on properly constructed track, (either industrial or overhead), propel a load of at least 20 times this amount. In

order to do the work in the least time possible, as large a load as possible must be taken at a time, so as to reduce the number of trips; for the man whether actually carrying the burden or pushing it on a car or suspended conveyance, usually comes back "light." Naturally strong and robust men are sought for such work, and in ordinary times these are not easy to secure and hold, so that the element of reliability calls for special attention in this connection.

With the wheel-barrow man lifts part of the weight and pushes all of it, which also applies to the two-wheeled truck, although in both instances by proper construction and proper loading, the weight can be largely balanced over the wheel or wheels, the man in the first case being obliged to keep it balanced both laterally as well as in the direction of travel, while in the second instance, but the latter is necessary. The effort required to push a load along depends largely on the eveness of the path for the wheels. To maintain a smooth and even path for transportation systems, other than either industrial or overhead tracks, is more or less difficult and requires runways floored with cement, iron plate or planks placed lengthwise, which requires frequent replacing, expecially where material is likely to be spilled and ground in.

Of course, all dirt, whether on planks, cement, iron plate or steel rails, offers resistance, the other forms of resistance, besides the inertia of the load to be overcome, being of mechanical nature, *i. e.*, chiefly a matter of proper bearing design, which will be further considered under the treatment of trolleys.

So, the question of *conveying* or *transportation* is *narrowed* down in a large sense *to industrial railways, overhead tramrail systems*, and *travelling cranes*, the cruder methods being dropped from consideration for the reason given.

ADVANTAGES OF OVERHEAD TRACK SYSTEM

Perhaps the earliest installations of the overhead trolley systems were made in provision houses and ice plants, where

trucking is impracticable and industrial railway systems out of the question, and where travelling cranes covering more space than necessary in one room or building without offering practical means of connecting with another, are, therefore, out of place, besides being too expensive.

The advantage of having a track on which the load can be easily propelled, *without the need of attention* to *keep it clean*, and *without monopolizing floor space* for a track, commends the overhead trolley system especially to the foundry where floor space is usually at a premium.

In fairness to the industrial railway system it must be stated, however, that unless trolleys used on the overhead system are operated iether automatically (*i. e.*, the load started at one place and automatically stopped at another), or unless the operator travels along in an attached cage, an aisle of some kind is necessary, because the operator cannot jump over flasks, molds, castings, in walking along under the trolley, etc. Provision is often made, however, so that the trolley can be operated from a distance and the aisle need not be directly under it.

As regards the cost of installation between the two systems, the overhead system usually has a little the advantage over the industrial railway, if the latter is properly constructed, the comparison including switches, turn-tables and similar accessories in both systems.

In some instances the industrial railway may be more cheaply installed, especially where an overhead system would require special bracing or trussing of the roof or other surfaces from which the track is to be suspended, and where heavy loads are to be handled.

In a foundry designed for and equipped with overhead trolley systems a *change in the arrangement* of the floor space, to accomodate different classes of work, can be *accomplished with* greater *ease* and at less expense than in one equipped with an industrial railway, and the flexibility of the former

system is simply astonishing, especially when used with electric power.

As a matter of economy the equipment of a foundry (or any other plant for that matter) should be used as nearly to its full capacity as possible. The overhead trolley system embodies superb possibilities for increasing the output of a plant, by bridging over some of the gaps left by installation of special cranes with limited spheres.

USES AND POSSIBILITIES

Take for instance a foundry for ordinary jobbing, catering to all classes of work: You will find a department, where all the heavy work is done, containing either a traveling crane of 15 to 50 tons capacity or several jib cranes, so arranged that two can be used together on the heaviest work which is likely to come into the shop, at the same time serving the cupola. If this foundry department has a span of 65 to 75 feet, the cost of a traveling crane is equal to the cost of several jib cranes of half its capacity and the service obtained is in favor of the latter, though for convenience, especially in transporting material, the former has no peer. A monorail system here would be out of question, as it could not be made to cover enough space to handle all the molds, besides requiring an unusually massive roof construction or special structure for supporting the tramrail, which might be in the way, saying nothing of the impracticability of carrying heavy loads (over ten tons) on the lower flange of a single beam.

However, in handling the iron from the cupola to the places where the light floor work and the bench work is done, the travelling crane can render service only to the end of its runway (taking for granted that it serves the cupola), from where the iron has to be handled by an overhead trolley system or on an industrial railway, from which in turn it is either transferred to jib cranes, or light travelling cranes which serve the light floor work department, or else the iron is poured from the large crane ladle, into bull and hand ladles, an operation not practical with industrial railway

systems unless special ladle cars are used, or special attachments (to support the ladle shank) are secured to the regular cars. With the overhead system such special features are not required.

The trolley system can go farther, even in this matter of handling molten metal, after its competitor (the industrial railway) has reached its limit. By means of switches the trolley with its load (in this case the ladle of iron) can be run on to a jib crane or onto a travelling crane or on to a gantry crane and serve the entire floor space covered by these, automatic provisions being made to prevent it from running off the track, at transfer points. Such a trolley on any of the various ji b or travelling cranes, after handling the molds on its floor all day can be made to go to the cupola to get iron and after being used for "pouring off" and "shaking out," can be made to handle the flasks, taking them to and from the proper storage place, and can handle the sand in the same manner, where systems have been designed with all these possibilities in view. Thus, castings can be taken from one floor to the cleaning room and a load of sand brought back if the bins be near the cleaning department, as they usually are, before the molders report for work, and the number of trips thus reduced to a minimum.

Working very harmoniously with this overhead track system is a scheme in which one end of an I-beam is suspended by a pivotal support, the other end being carried on wheels running on a circular suspended track, on to which the trolley can be run, allowing a large area to be covered without the annoyance of masts or columns breaking up the space.

We have mentioned various types of cranes, but only their functions as a means of conveying have thus far been considered, although the name implies ability to lift (weights) as well.

We see from the foregoing facts that as to flexibility and co-operation with other systems, with the least amount of handling of loads in transferring, the over-head trolley sys-

tem certainly holds a unique place, and has some decided advantages over the industrial railway to which may be added that loads can be picked up from points outside of the perpendicular and also so lowered, especially where the trolley track is high above the ground.

Both systems can be made to run up inclines by proper application of power, although this is seldom necessary in the overhead trolley system because the track can usually be supported so as to be level, regardless of variations in the ground level.

FIG. 1.

VARIOUS KINDS OF TRACK

Special attention should be given to the track, which can be constructed in various ways, the simplest form being that of a *rectangular bar* (Figs. 1 and 2) supported from the

wall or ceiling by means of cast iron or malleable iron hangers, the trolleys used being of very simple construction, usually with one or two wheels running on the top surface of the rail, and capable of being readily taken off the track, which is of special advantage where meat hooks and similar attachments are a part of the trolley. This is the most primitive type of overhead tramway system, referred to previously.

FIG. 2.

Another, but rare type, employs *two channel beams* arranged either back to back or face to face, with an adequate space between them in which operates that part of the trolley to which the hoist or load is attached. The wheels of the trolley (usually four in number) run on the top flanges (beams back to back), or on the bottom flanges of the beams (face to face), respectively, due provision being made to have the hangers for this type of track also act as separators. It is

probably the most expensive kind of tramrail, without having any particularly meritorious qualities.

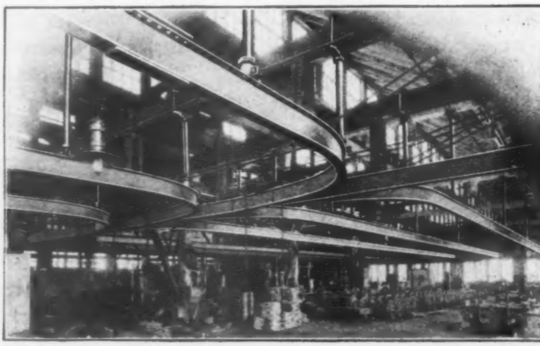

FIG. 3.

The *Plain I-Beam Track* (Figs. 3 and 4) is used perhaps more than any other form, the trolley wheels running on the lower flange of the beams, while the supports are attached to the upper flanges. To obtain the most satisfactory re-

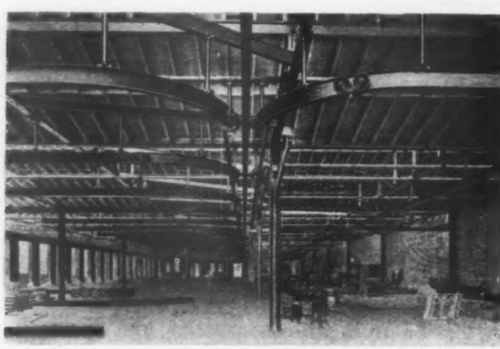

FIG. 4.

sults, the beams must be carefully straightened before being erected and the ends should be sawed rather than sheared.

Special attention must be paid to splices and switches so as to have a minimum gap at the joints, and curves must be very smooth, particularly so, where trolleys are operated at high speed (*i. e.* from 600 to 800 feet per minute). Any jar due to an uneven track is communicated to the entire trolley mechanism and load, and in motor driven outfits, parts of the machinery are thus often loosened or broken, merely because of a rough and poorly constructed track.

Yet another form of track is the *Coburn Track* as shown in section in Fig. 5, which, due to its very construction,

FIG 5.

has the special advantage of keeping the surfaces, on which the trolley wheels, run, clean and dry. The latter is of considerable importance when used out of doors. Being made of smooth rolled steel, the wearing surfaces present less resistance to the trolley wheels than any other track known. This advantage in connection with the construction of the

FIG. 6.

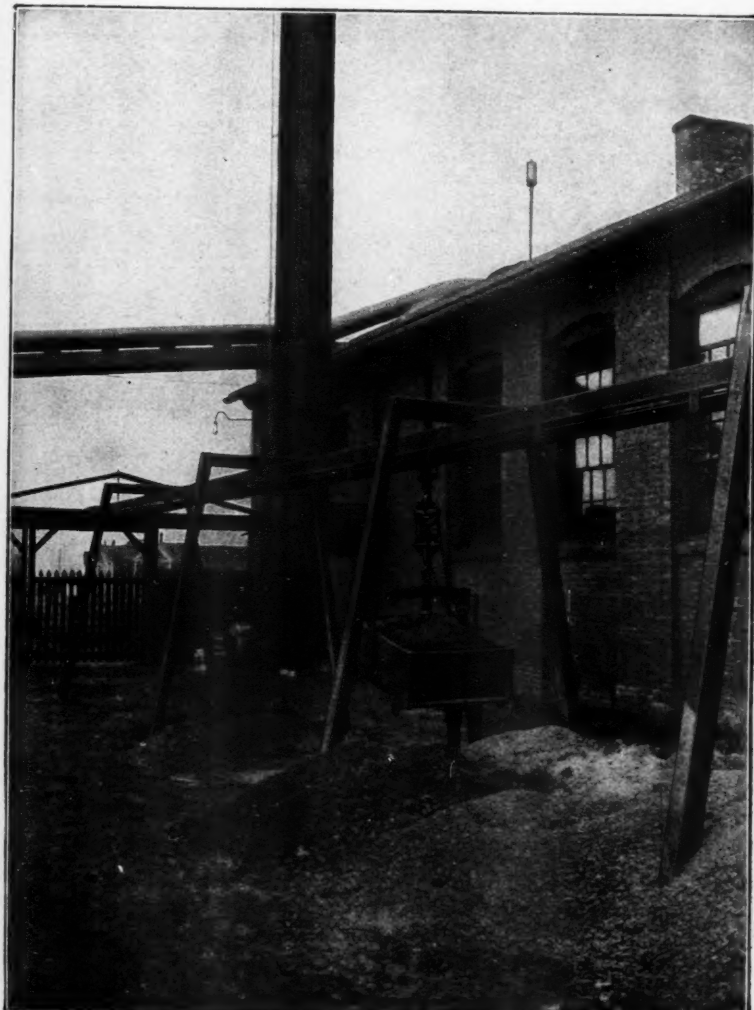

FIG. 7.

FIG. 8.

special trolleys for this track, which have roller bearing axles, enables a load to be moved with very little tractive effort. However, Coburn Track is at a disadvantage on account of requiring supports at frequent intervals, necessitating the construction of an I beam track, practically the same as just described (Fig. 6), or an equivalent wood construction (Figs.

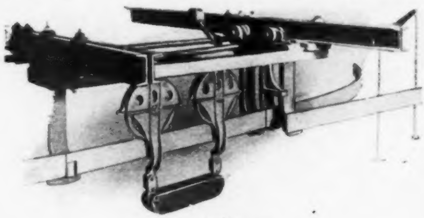

FIG. 9.

7 and 8), from which it can be suspended. A further disadvantage is its limited capacity which is restricted to loads of about 4 tons.

Finally, the *round bar* type of trolley track might be mentioned, such as is used on stove ladders, but its scope

FIG. 10.

is confined principally to light loads and short spans, and need not be considered as a distinct type of overhead trolley system.

Practically all of these types of track can have switches,

(Figs. 9, 10, 11), cross-overs (Fig. 12), transfer bridges, turntables (Fig. 13), and scales, but the second and last (channel

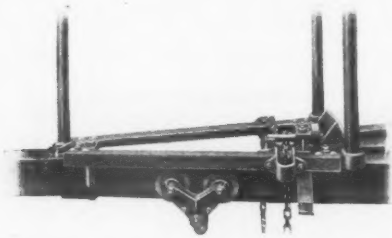

FIG. 11.

beams and round bars) do not lend themselves well to such features.

TROLLEYS

The most expensive trolleys are those which can be bought at the least cost. These are usually solid iron castings, made of one piece, with very inferior bearings, such as steel studs, cut from cold rolled shafting, set-screwed into the casting or even cast in, the unbushed wheels being mounted on the inside projection of same.

So it happens that if the lower flange of the trolley track has little irregularities, the entire load is thrown on two or three bearings, instead of all, and this may produce so excessive a pressure at any one bearing as to cause "cutting," which in turn causes great resistance to be offered to the propelling of the load.

These variations can be compensated for by having the trolley frame made up of two parts, one for the wheel or pair of wheels on each side of the beam, these halves being secured together by a pivotal connection as in the Brown compensating steel trolley (Figs. 14, 15 and 16), or the Curtis trolleys using steel castings instead of plate steel sides but otherwise employing the same principle (Figs. 17, 18, 19).

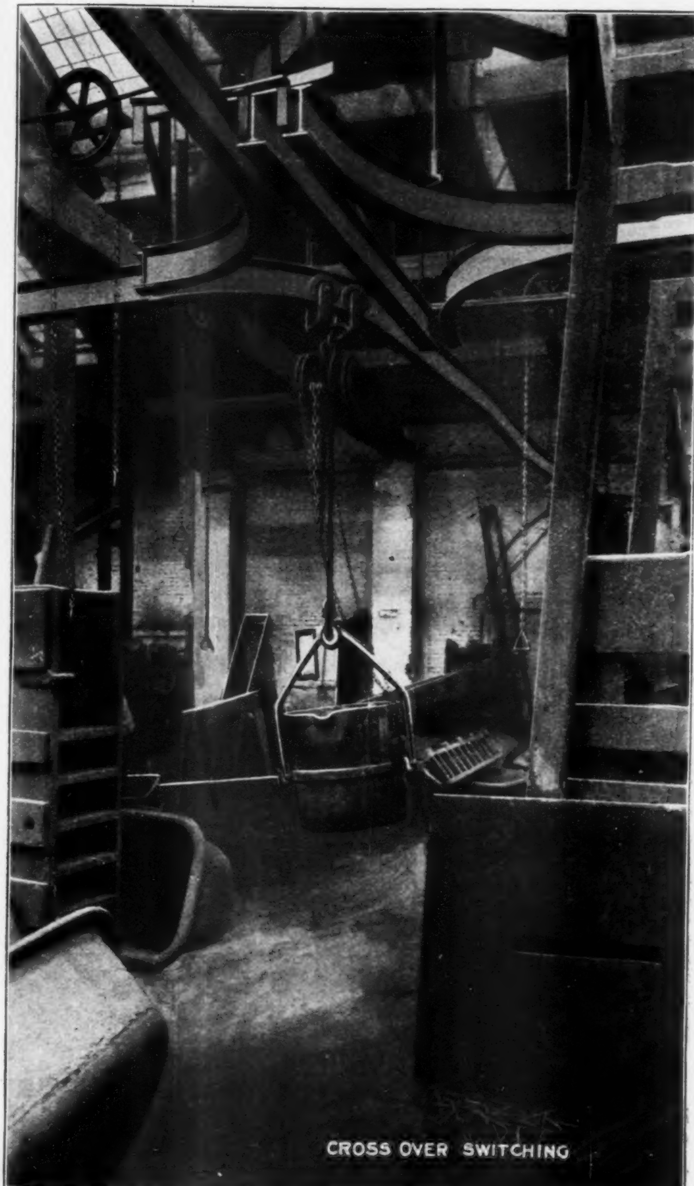

FIG. 12.

Figures 15 and 18 show in section the bearings of well made trolleys, the one bushed, the other provided roller with bear-

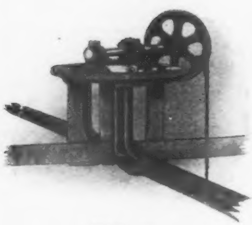

FIG 13.

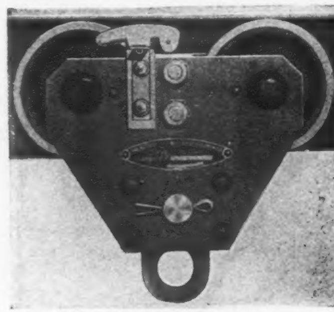

FIG. 14.

ings. Some builders use ball bearings. In any event the bearings should be ample in size, and the treads of the wheels should be machined, or "chilled," and preferably also ground.

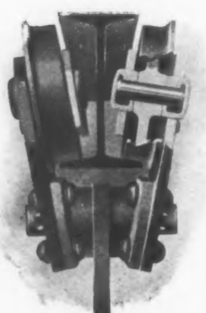

FIG. 15.

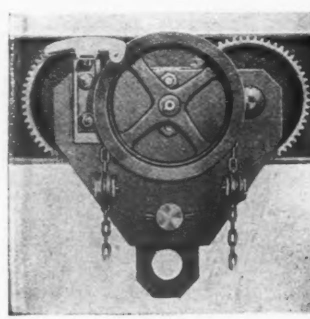

FIG. 16.

Figure 20 shows the plain construction of a trolley for a bar track system. In the case of power hoists, the same motive power is usually applied to propelling the trolley as is used on the hoist.

As to whether a plain (Figs. 14 and 17), hand geared (Figs. 16 and 19), or motor-driven carriage (Figs. 28 and 30) is to be used, depends largely on the amount of use and

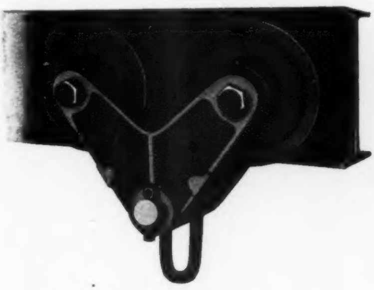

FIG. 17.

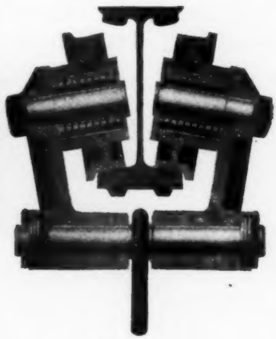

FIG. 18.

whether this warrants the expenditure, and whether the track is near to the floor or high up. If the loads are light and the track is near the floor a plain trolley or carriage will

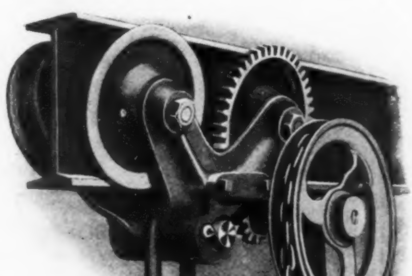

FIG. 19.

usually answer, but if the loads are heavy, 2000 pounds and upwards, or the track is high, either a hand-geared carriage, or one propelled by some motive power should be used (de-

pending on the type of the hoist), because in such cases the plain trolley cannot be started and stopped conveniently and accurately, it being necessary to push the load a considerable distance out of the perpendicular before the force applied is sufficient to start the trolley, and once started, its progress is usually "jerky." It is very obvious that with a motor-

FIG. 20.

driven carriage large weights can be handled by boys, which is quite an item in the operating cost. We must also consider the fact that any man's ability to walk and lift is limited, and he will *handle more work with a motor-driven carriage*, especially one in which the operator can ride along in a cage, as referred to later in the description of complete outfits. The speeds of motor-driven carriages vary from 250 to 800 feet per minute, 350 being a popular rate. Most of the motor-driven trolleys are provided with rheostats for controlling the speed.

THE HAND HOIST

The block and tackle deserve hardly any attention in this connection, since the rope will not stand the action of

molten metal or hot castings, nor even the heat from same, to which it is likely to be subject when used in the foundry.

In the line of chain blocks there are "Differential," "Duplex," and "Triplex" hoists, for which a maker gives the following data as to efficiency (*i. e.* the actual work in foot-

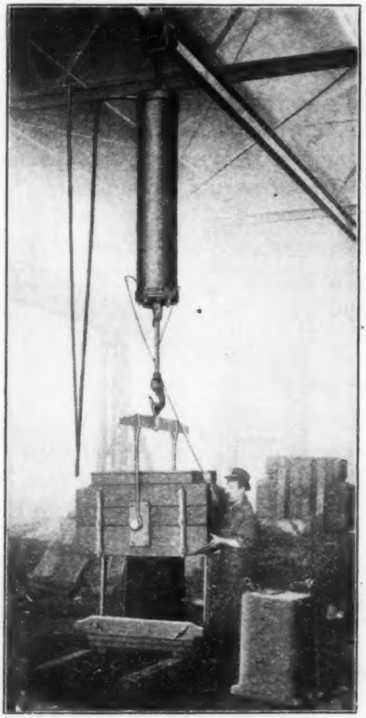

FIG. 21.

pounds, done at the hook, divided by the effort in foot-pounds required to do it), 35%, 50% and 100% respectively.

The same builder gives the following comparison of performances recorded as an average: With the same exertion, a man can lift 800 pounds at the rate of three feet per minute on a differential block, 1700 pounds at a rate of two feet per

minute with a duplex block, and 2000 pounds at a rate of four feet per minute with a triplex block.

Comparing these figures with the lifting speed of air hoists (10 to 25 feet per minute), and that of electric hoists (10 to 50 feet per minute), both having neat speed control—the former by means of a throttle, the latter with the aid of a rheostat—it must be admitted that, while the hand hoist has its field where the expense of a power hoist is not warranted, especially in cases of infrequent use, this field of application is becoming very limited; so that, though at one time the hand hoist was quite a favorite, it is being rapidly replaced by electric or pneumatic hoists.

AIR HOISTS

Pneumatic hoists are very convenient and cheap in many places, especially where the loads are light, the travel of the trolley, to which they are attached, short, and the air pressure reliable.

Most foundries are equipped with a compressed air plant for use in connection with pneumatic riddles, chippers and sometimes sandblast, and so find it very economical to install the plain cylinder lifts, which are made in capacities up to

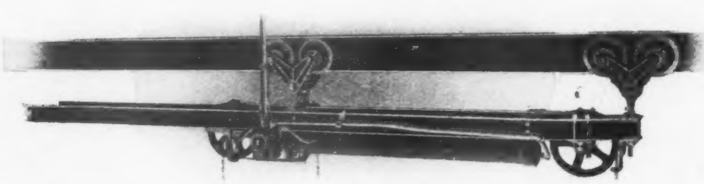

FIG. 22.

10 tons, though seldom used for loads exceeding 3000 pounds, above which the geared pneumatic hoists are usually employed.

The chief limitations of air hoists make themselves felt

when trolleys on which they are used are required to run over considerable distances. Then the matter of handling the air supply hose often becomes very awkward.

If there is much moisture in the compressed air, trouble is frequently experienced in its freezing when the air expands, thus obstructing the air passages of ports. This objection, however, applies more to the geared hoists with their many and intricate parts rather than to the old and reliable "straight lifts" (Fig. 21) or to a modification of same employing a cable (and sometimes block) and hook (Fig. 22), on the same principle as hydraulic passenger elevators.

At one time, considerable objection was raised to the "springy" action (cushioning due to the inertia of the load) of air hoists, which made it difficult to move a load very slowly and stop it accurately. This difficulty, however, has been entirely overcome in the Curtis "air balanced hoist" which admits compressed air to both sides of the piston and exhausts, under control, from one side, as contrasted with the old "straight lift" in which one side of the piston is always exposed to atmospheric pressure.

It is a strange and significant fact that nearly all manufacturers of pneumatic hoists have also taken up the manufacture, or at least the sale, of electric hoists, while the manufacturers who started out to make electric hoists have stayed in the business and "waxed strong."

ELECTRIC HOISTS

The development of the electric hoist was prompted by an effort to meet a demand for a power hoist in places where it would be difficult or impossible to install a travelling crane.

The first electric hoist was merely a motor driven chain block, which has since been perfected in design, a number of refinements being added such as speed controllers, limit devices, etc. Later it became evident that, for smooth action, the chain, with its tendency to jerk as the links slide into

the recesses in the chain sheave, must be replaced by wire rope, and to prevent this from leaving the score in the drum, due to side pulls, rope guides were provided.

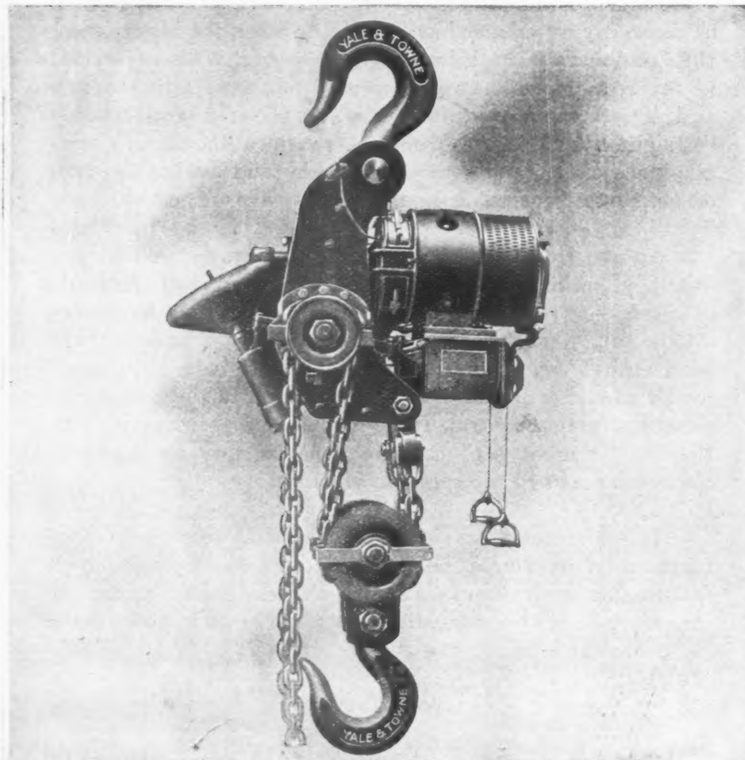

FIG. 23.

In the first electric hoists the speed reduction from the motor to the drum shaft was accomplished by a worm and worm-wheel transmission, the worm being driven either by a bevel gear meshing with a pinion on the motor, as shown in Figs. 23, 24, 25, 26, or by a spur gear meshing with a pinion

on the motor as shown in Fig. 27. This "worm-gear type" of hoist is still extensively manufactured and, though a great deal of fuss is often made over the low efficiency of worm-gear transmission, especially by salesmen of hoists

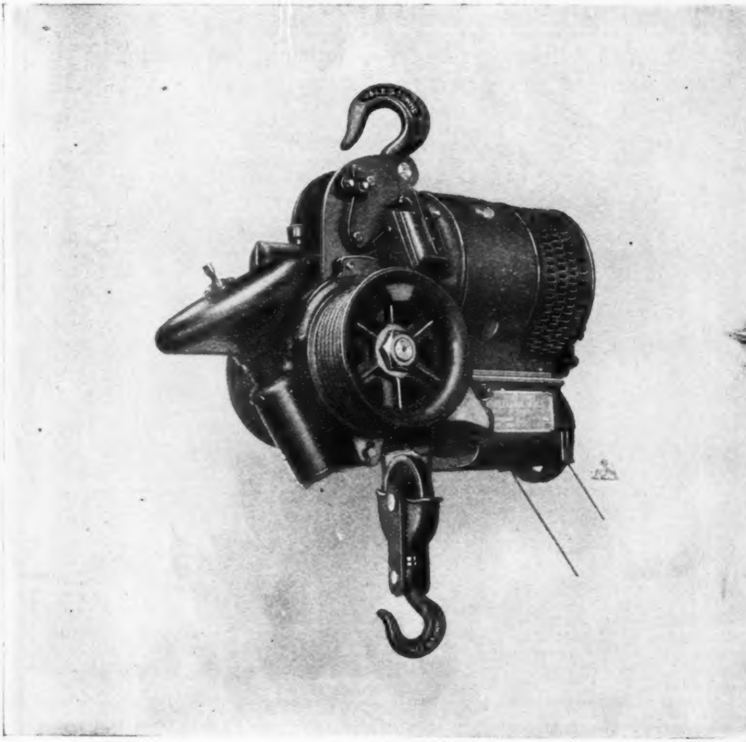

FIG. 24.

which do not embody such, it is very apparent that when the cost for current is almost negligible (sometimes as low as ten cents per day on five ton hoists, for an average amount of usage), the difference between the operating expense of a hoist using a worm-gear transmission and one

which does not, is a matter of trivial consequence. On the other hand a hoist employing a worm-gear transmission has the charactersitic of never "running away" under load, unless the worm be made of extreme pitch. This advantage,obviates the necessity of the delicate "load brake," necessary in other hoists, all of which has a significant bearing on the relative prices. Furthermore, worm-gear hoists usually embody such refinements as thrust bearings and are not nearly as wasteful of power as generally understood.

FIG. 25.

The "Spur-gear hoists" (as those not using the worm-gear transmission are often called), lend themselves more readily to compactness in design and are the only type used for capacities above six tons (Fig. 28), although they are also made for capacities as low as 1000 pounds (Fig. 29) and less.

In Fig. 30 is shown a hoist of this type on a motor-driven carriage, both trolley and hoists being controlled from the floor, in this case from a remote point, by the aid of an "outrigger" enabling the operator to more comfortably handle hot metals and similar loads than would be possible

with pendant controller ropes (Figs. 23, 24, 25, 26) or pendant rods (Figs. 27, 29). Sometimes this outrigger is placed at right angles to the position shown, so that hoists and trolley

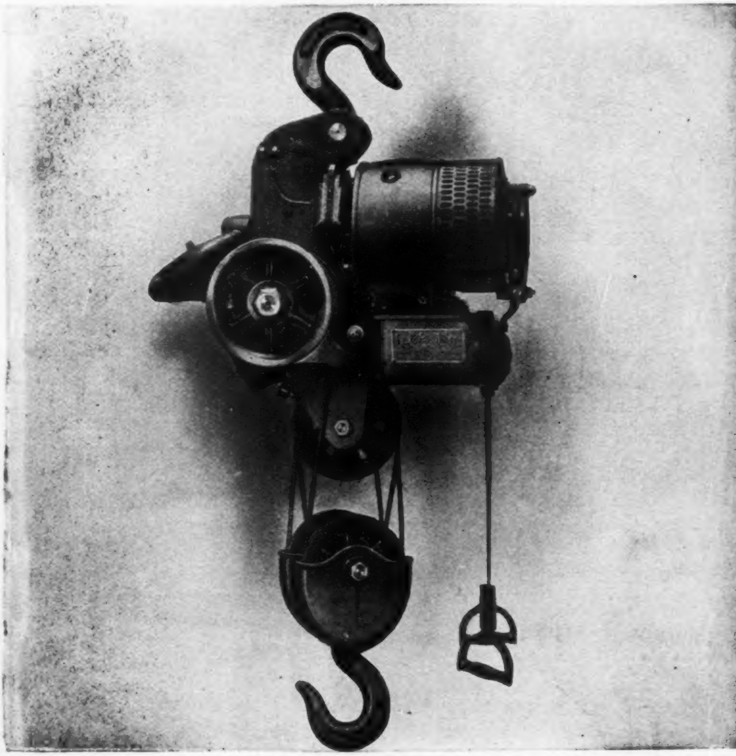

FIG. 26.

serving a wheel-pit, for instance, can be operated from the side of the pit.

In calling attention to some particularly interesting features, we would refer to Fig. 23, employing chains in-

stead of wire ropes and by being equipped with a suspension-hook, the hoists can be readily removed from one place and used in another. The latter feature is also shown in Figs. 24 and 26, which cuts are inserted principally to show how one hoist with two ropes as Fig. 24 (and 29) can be made to handle double the load by using four ropes as in Fig. 26 (and 28) with a corresponding sacrifice in hoisting speed;

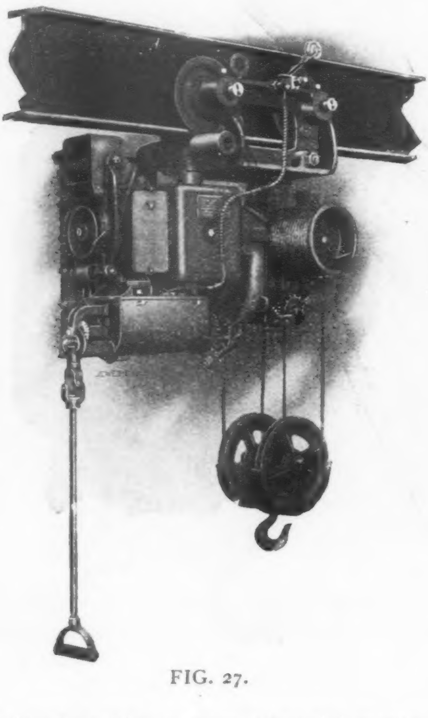

FIG. 27.

otherwise a larger cable, a more powerful motor and a correspondingly heavier frame and gear train will be required. This will explain why the price of a hoist has a close relation to its foot-pounds capacity and why this price may vary between wide limits for the same capacity, depending on the hoisting speed.

Fig. 25 shows a hoist on a plain trolley and Fig. 29 on a hand-geared trolley, which have been referred to before.

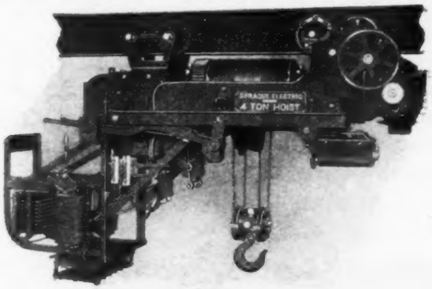

FIG. 28.

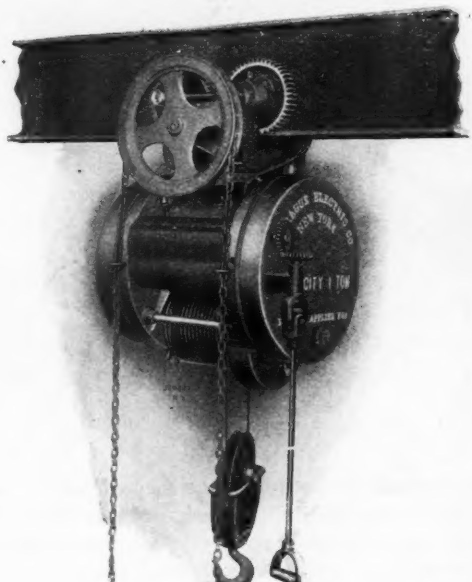

FIG. 29.

Fig. 28 shows a hoist and trolley equipped with an open operator's cage. Such cages are often made totally

enclosed with glass sides when used for out-door service. A combination of this kind is usually called a monorail crane, all operations being controlled from the cage, sometimes even the "throwing" of switches.

A feature of special interest to foundrymen is the "foundry type controller" (Fig. 29), which is usually rod-operated, its special merits lying in the fact that the upper and lower limits of travel can be fixed at any desired points, so that

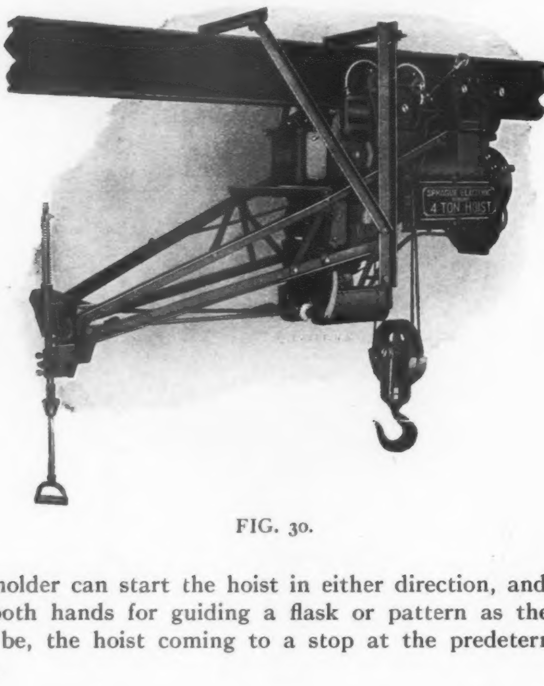

FIG. 30.

the molder can start the hoist in either direction, and then use both hands for guiding a flask or pattern as the case may be, the hoist coming to a stop at the predetermined limit.

The load brake previously referred to consists essentially of a series of discs, one keyed to the intermediate shaft, one operating on a screw, and a third engaging a pawl, so

related that the tendency of the load is to tighten the discs, while the reverse motion of the motor tends to separate them; thus, by a delicate counteraction of these two forces a smooth, non-accelerating motion is obtained in lowering. In addition to this load-brake there is a solenoid brake, which act by springs, whenever the motor armature circuit with which it is in series, is broken, since the brake shoes are kept apart by the action of the solenoid counteracting the spiral spring. These brakes operate on brake pulleys attached to both the hoist and trolley motors. More has been said about the electric hoist because it is the most complicated and because its scope is wider than that of the other hoists.

GENERAL TREND IN SELECTION OF HOISTS.

The writer has taken pains to secure unbiased expressions from a number of prominent concerns as to their experience with all kinds of hoists, and the general favorite seems to be the electric hoist.

Here are some interesting quotations:

"We do not feel that we can afford to use hand chain hoists (where there is any considerable hoisting to do in a day) as compared with electric hoists. In our foundry over our molding machines, we use electric hoists."

"It is difficult to estimate the profit of these hoists (electric), but we will say that we have considered them justifiable in positions where they would be used about once an hour, and are still governed by this rule. In regard to cost of maintenance of these hoists, we have not found it excessive, though it is a moderate item." This was said by a manufacturer who uses many of these hoists on plain traveling crane bridges (frequently these are made of simple, or double, I-beams mounted on two-wheeled trucks, which allows such a ready combination with an overhead trolley system) on the side floors, the control (in this case pendant ropes) being located near the end of the bridge, i. e., near the

columns supporting the runway, where an aisle is desirable anyway. See Fig. 31.

"We were formerly equipped with chain blocks, which are, of course, very slow when even the best makes are used. We desired, however, something that would handle our work more quickly and thus permit us to increase our output, which is the essential factor in the machine-shop work after all, except, of course, the quality of one's work. Upon investigation we decided that the ...... hoist was the equal, if not the best on the market, and after installing one of them we gradually added to our equipment until we now have about ten or twelve of them, varying in size from one-quarter ton to four tons, and our expectations of increasing our output in the departments where they are used was more than realized. We will undoubtedly add more of them from time to time, although where a hoist is only used occasionally we think that the chain block will suffice, owing to the small investment necessary. In serving our heavy planers with castings and in our erecting departments where we require more than one man to lift a piece, we found ...... electric hoists very serviceable, in fact, a great deal of time is saved in this way because the *adjustment* is so *close* and *accurate* that a man can lift a heavy piece very quickly and drop it into place as convenient and handy as if it were of a few pounds in weight only."

"There is absolutely no question about the value of the ...... electric hoist, over hand hoists, where continuous work is being performed, not exactly continuous work, either, but we mean where a considerable number of pieces are being handled, and I think a possible purchaser would only have to compare the two in actual operation to be convinced beyond any question of doubt as to the desirability of using an electric hoist for such work as we have described, and, of course, on similar work. We have kept no accurate cost of the maintenance of the various hoists of ...... which we have, because it is trivial, comparatively, and we have not found it more expensive than the running of an ordinary lathe or planer." In these statements reference is made to

the "close and accurate adjustment" possible with electric hoists. This brings to mind a number of instances which came to the writer's notice where pneumatic hoists were replaced by eletric hoists, especially in the operation of handling work at a riveting machine in structural and boiler shops, because the spaces between any two holes are so slight that a very accurate and at the same time, speedy adjustment is required. The electric hoist "filled the bill," but so does the newly developed "air balanced hoist."

"In response to yours ———, I am pleased to say that we have always been well pleased with the change we made from chain blocks to electric lifts for our small hand cranes. In addition to the fact that we have had occasion to lose no time by reason of faulty construction, we have gained a great deal of time in the actual doing of work, in fact so much that we should not like to be obliged to go back to the old method under consideration. The cost of maintenance has been so trivial as to hardly call for remark."

"Replying to your favor ——— in regard to ...... hoists, will state that we have air hoists here, we have a number of chain blocks and hereafter we will not consider any equipment except electric hoists. Several of our crane runways have two cranes on them, one a ...... electric hoist and the other one a hand hoist, and we notice in going through the shop that it is always the electric hoists that are in use. This is the best recommendation that we know of."

"Replying to your inquiry ——— as to the advantages of the electric hoists over the chain block, we would state that in our opinion the first and greatest advantage is the rapidity with which pieces may be handled, and secondly the reduction in the number of laborers necessary for operating the chain hoists, and lastly, if the hoist be operated by the machine operator himself, the freedom from strain of pulling on the chain block and consequent spoiling of the operator's touch, this being especially important in the case of the machine hands who are called upon to use micrometer calipers, as the pulling on a chain hoist is known to seriously affect a

man's ability to caliper carefully afterwards. We installed our first electric hoists—one four-ton and two two-ton ...... hoists—in the winter of 1904, and these three hoists eliminated one laborer at $9.00 per week, the original cost of the hoists being about $1,200, as we recollect, and in addition we were able to lift three or four times as much as before. We now have in operation the original three with the addition of a five-ton electric hoist and two fifteen ton cranes. At the time we eliminated the laborer above referred to, we had about twenty-five men—we now employ more than three times that number so that we are still running a comparatively small shop, but one in which all of the pieces to be handled are too heavy for one or two men to lift by hand, and therefore the amount of hoist work in our shop is considerably greater than you will find in a shop three times its size where the product is light, this may be used as an argument against the use of electric hoists by the manufacturer turning out light stuff, but we can assure you that anything which is heavy enough to be handled by a chain block should be handled by an electric hoist on account of the three advantages mentioned. The repairs on our entire equipment are trifling and consist mostly of new carbons with here and there a set new of fuses from time to time."

"We have your letter ———, and take pleasure in briefly relating to you, our experience with ...... three-ton electric hoists. We are at the present time using about twenty-two (22) of these hoists, each attached to a specially designed traveling crane. One of these hoists is placed over each floor in a portion of our foundry and is equipped with special foundry control. We are likewise using them in the machine shop very successfully. Before we installed these electric hoists, we were using a small hand crane of our own design. These cranes would lift only about 1500 to 2000 pounds, but were exceedingly convenient for work up to these weights. The cost of operation of the hoists which we were using was about the same as that of ...... electric hoist. We have kept no accurate data as to the comparative cost of maintenance, but can say that on the whole the maintenance cost has been reasonable. We have found a system,

such as we have laid out here in which each floor has its own equipment, a very flexible system, and in our opinion for the character of the work which we have had to handle, very greatly superior to the bridge crane arrangement. Of course we cannot handle castings with the size of hoist we have, over three tons in weight, but it is very seldom that we are called upon for a very heavy casting, and hence, we are not operating with them at a disadvantage. We have an equipment in another portion of the foundry which will handle castings up to ten tons in weight, and all our heavy work is done here. In short we are very greatly pleased with our overhead trolley system and are always ready to recommend the ...... electric hoist to any one for the reason that it has given us the utmost satisfaction. It is simple, substantially built, and its operating cost in general is low."

SUGGESTIVE INSTALLATIONS

A certain railroad company at its wheel foundry uses 34 electric hoists equipped with foundry control, the hoist as well as the trolley, which is motor-driven, being controlled by manipulation of a pair of handles supported from an outrigger attached to the hoist, so that they can be operated from one side of a pit as previously explained. Space prevents giving a detailed description of this plant, but it may be said that the hoists are used on a monorail system which has been substituted for a series of jib cranes as the latter was so slow that the men handling the ladles would not use them, with the result that smaller ladles were used which called for more men, caused interference in pouring and loss of time. The hoists in question are used for molding, pouring, shaking out and delivering castings to an industrial railway from which they are taken by a bridge crane to the annealing pits. In this connection it is interesting to note that the electrician of a certain car-wheel foundry, using over 12 electric hoists, has made the following tabulation, which is but an extract of a very complete report: 300 wheels cast under twelve hoists (under test) requiring 1,828 movements for lifting, 3,008 movements of trolley, or a total of 4,836 movements. 41,800 Watt-hours were used by these

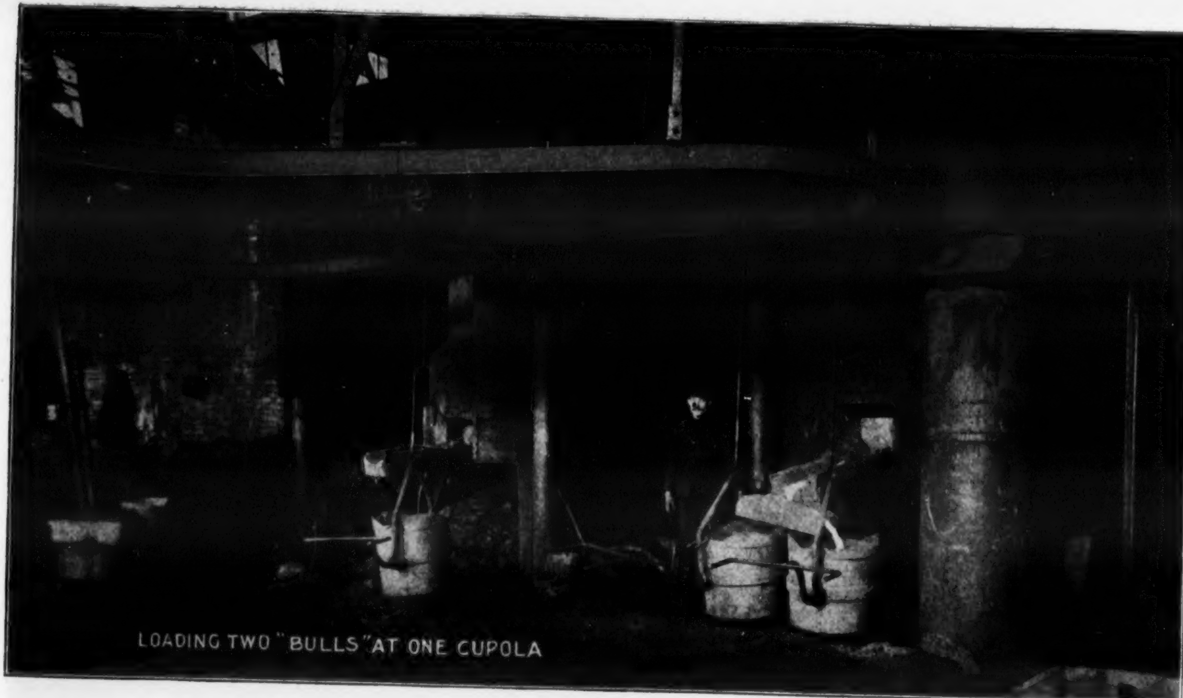

FIG. 32.

FIG. 33.

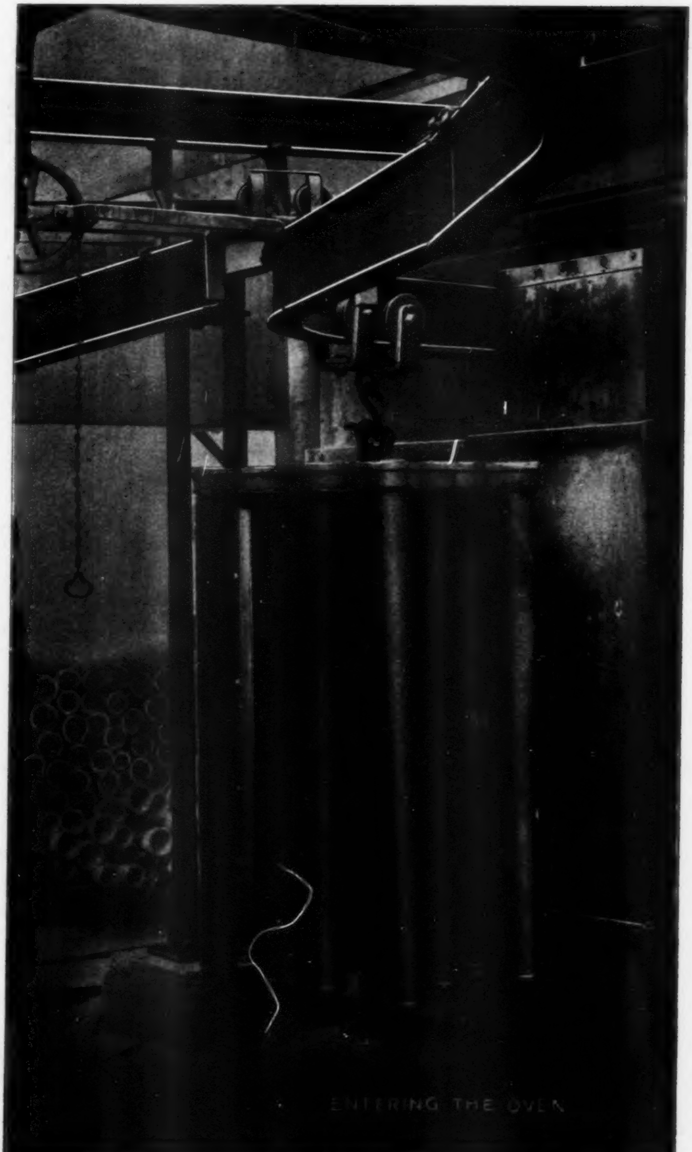

FIG. 34.

hoists for this work in one day, which, on the basis of the cost of current for that foundry, brought the cost of current consumption for the hoists to 22 cents per wheel cast (138.2 Watt-hours per wheel), which is negligible. So it would seem that it pays to get central station current in cases where there are no individual power plants.

Another electrician in a plant, using 14 five-ton hoists, made close observation and for a period of seven months, and figures that the labor, cleaning, oiling, repairing, new parts cost but 96 cents per ton capacity of the hoist per year.

A large pump manufacturer uses 96 hoists of one make, some on jib cranes, some on bridge cranes, and 38 of this number on single I-beam bridges over the machine molding foundry.

A great many other concerns might be mentioned who purchased from 4 to 32 electric hoists from one maker, in each case to improve on former methods, one reason as yet unmentioned being the observation that handling iron in small ladles and a greater number of these, not only causes such a large percentage of lost castings due to dull iron, but also unnecessarily increases the pay-roll for common labor.

Fig. 32 illustrates a Randall installation for handling crane ladles and especially track construction around a cupola. Fig. 33 shows how sand is taken to the molding floors on a similar installation and Fig. 34 shows how cores can be run into the oven and left on the trolley till dry, on a similar overhead trolley system; the cut also shows switch construction.

In Figs. 35 and 36, a two-ton electric trolley at a foundry is shown serving the cupola instead of an elevator.

It will be noticed that the railroad track is immediately outside of the cupola house, an extension from the charging floor hanging partly over same. Along side of this track the

FIG. 35.

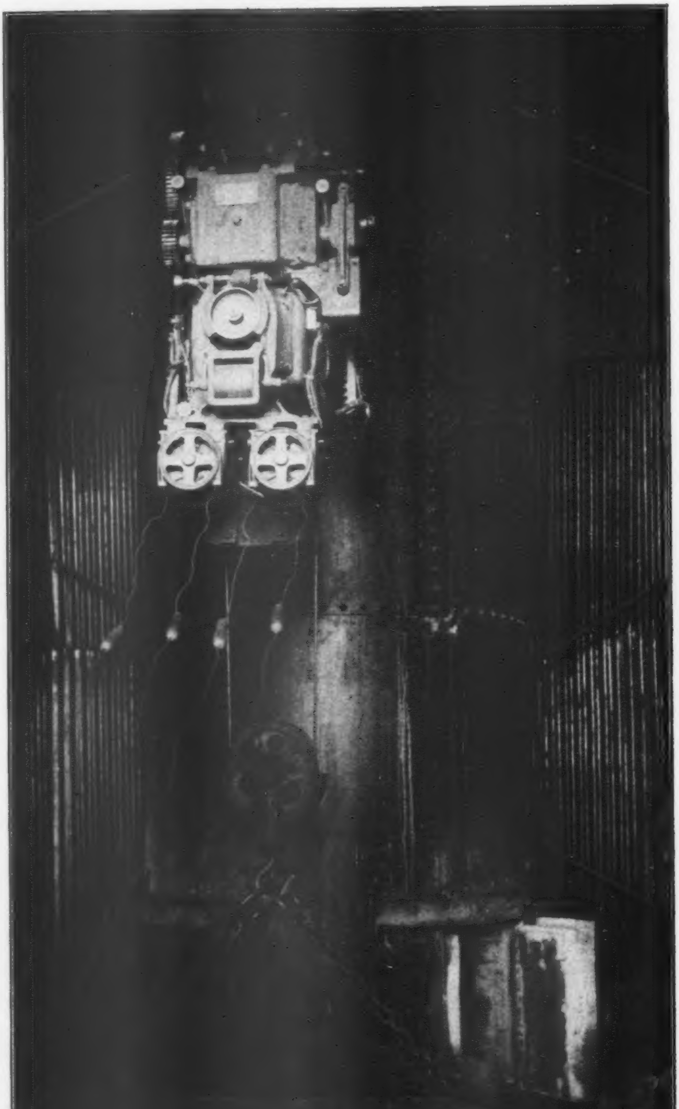

FIG. 36.

pig-iron, scrap-iron, limestone and coke storage piles are made, on the side opposite the cupola house, and the sand-bins are in a shed adjoining the cupola house. An extra rail is put in between the two tracks which accommodates the industrial cars, which are run along the stock piles, filled, run under the overhead track shown, extending across the railroad track, and then lifted up by the crane as shown, the

FIG. 37.

pendant controller ropes being so arranged that the hoist can be operated from below as well as from above. Fig. 36 shows how close to the cupola the charge can be taken by the hoist. In fact with a specially constructed bucket, such as are frequently used for handling sand and coke, and as illustrated in Fig. 33, material of this nature can be discharged right into the cupola without transfer.

Fig. 35 also shows another overhead track at the end of the foundry, which is used largely for loading castings into the cars, and at present is served by a hand or chain hoist. This is found too slow and tedious, however, and a connection between the cupola track, and it is contemplated, so that the electric hoist can be used to load the cars.

Fig. 37 represents a monorail crane serving the cupolas and storage yards, even the cinder mills of the large stove foundry. It will be noticed that here the entire runway is covered and of wood construction. Its entire length is 1500

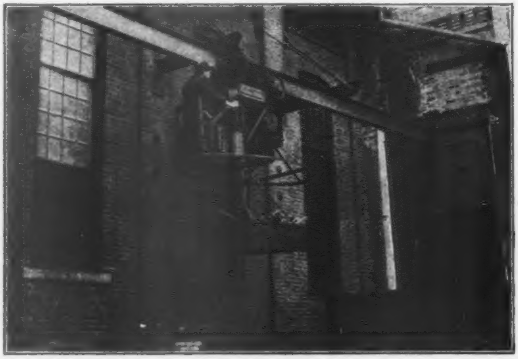

FIG 38.

feet. This monorail crane (three-ton capacity) handles all of the material for the cupola, taking it right into the charging room as in the previous case illustrated. The company paid between three and four thousand dollars for the entire installation and believe that they have effected thereby, a saving of $15.00 per day over their former method of getting the material from the stock yard in wheelbarrows and employing a platform elevator at each cupola for raising the material to the charging floor. They pronounce the system as very successful and state the repairs are trifling, overhauling being done but once a year. There are three cupolas on this side of the foundry, all being served by this monorail crane.

Fig. 38 shows a monorail crane, inter-communicating between several buildings, and in the case handling castings. Note the arrangement for opening the doors, by means of the metal hoop.

Fig. 39 shows an electric hoist (floor operated by pendant ropes) bringing coal in dump-baskets to the boilers.

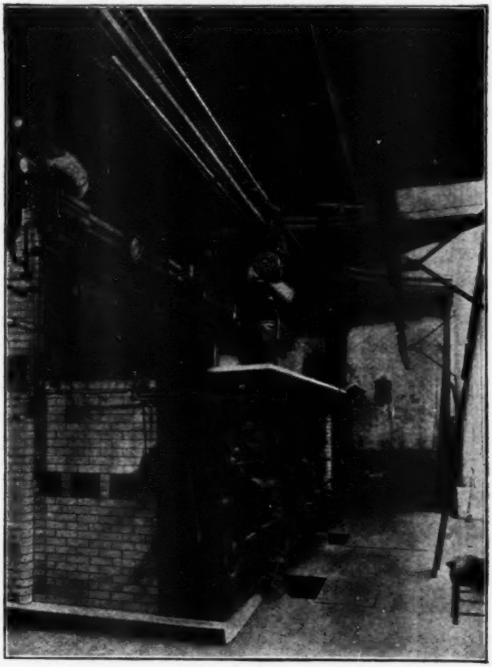

FIG. 39.

In foundries where a great deal of sand has to be handled an installation of a monorail crane with grab-bucket might be a paying investment.

Nothing has been said of the brass foundry, although this has been a very fruitful field of application of trolley

systems and hoists in handling pots, drawing them out of the furnace and conveying them to the floors for pouring. Hoists of all kinds are now made to stand the fumes of furnaces as well as of pickling vats nicely.

Thanks is due to The Curtis & Co. Manufacturing Company, The Sprague Electric Company, The Coburn Trolley Track Manufacturing Company, The Randall Tramrail Company, The Yale & Towne Manufacturing Company, for the courtesy of furnishing cuts, which we regret we could not use to full advantage because of the limited scope of this paper. Each of the different power hoists could be the subject of an exhaustive treatise.

If foundry men are getting a glimpse of the great possibilities of the overhead trolley systems and are led to thoroughly investigate the matter as a result of the writer's humble effort, he will be amply remunerated for his services to this convention.

Mr. Gaehr's paper, as read in abstract by Mr. Lane was well received, and after this, Mr. Lane gave an illustrated talk on the Electric Furnace, with special reference to its possible adaption to the Foundry. In the absence of a manuscript, we are unfortunately unable to reproduce the lecture here.

President Waterfall then called upon Mr. Moyer to give his lecture on "Overhead Transportation for the Foundry," which was a running discourse on the subject in connection with numerous lantern slides. Mr. Moyer, who is an authority on the subject, proved a very interesting lecturer, and he as well as Mr. Lane received the special thanks of the Association.

In the temporary absence of Mr. Ellsworth Taylor from the convention hall, his paper on "The 'Secrets' of Successful Modern Business Organization," was read by title.

OVERHEAD TRANSPORTATION FOR THE FOUNDRY

By A. W. Moyer, New York City.

Planning an efficient and economical method of transportation, of the many commodities used in a foundry, is a question which is receiving more and more careful consideration each year. The day of the wheel-barrow and industrial track for doing this is past, and all over the country new and better transportation facilities are under discussion.

The most efficient method thus far brought to the attention of foundrymen is a well planned, and a well installed system of *Moyer* Overhead Tramrail.

The purpose of this paper is to show you just what a tramrail is; just how it should be constructed. Most impor of all—how it should be installed.

Let us examine how a tramrail system is built. We will start at the rail itself. A standard section steel I-beam, in good straight, long lengths, makes the best possible rail. The section is sufficiently strong so that the hangers may be placed as far apart as 20 feet, and a ton-load carried.

This form of rail cleans itself of the foundry dust, and permits the use of trolley wheels of large diameter. At the joints the rails are secured by heavy splice plates, on the top, and one on the bottom. The joints are close fitting, and the trolley passes them with no jar or jump. The method of supporting the rails is of importance, as the rail must be hung from the roof timbers, or trusses, steel forged hangers are either bolted or lag-screwed to the trusses, if of wood, or clamped if of steel. At the rail, the most efficient method of attaching to the hangers is by means of a clamp.

These clamps are steel forgings so arranged that they clamp the top flange of the I-beam rail. It should be borne in mind that the cost of any tramrail system to the foundryman depends on, not only the price the manufacturer charges for his system, but the cost of the erecting must be added. It has been found that clamp hangers cost less to erect than any other style built, in that there is presented the opportunity with a horizontal as well as a vertical adjustment.

No matter how carefully built, few foundries can be found wherein the trusses are spaced accurately, nor will those trusses be found to be level. Necessary adjustments are well taken care of by these clamp hangers.

An easy running trolley is an absolute necessity to an efficient system. The trolley here shown has cast iron wheels, forged steel yokes, set on a forged bed plate, with a steel forged eye. The trolley swivels, so as to easily turn curves of as small a radius as 30 inches, though a curve of four feet radius is the standard, and is used whenever possible.

The wheels revolve on turned steel axles set in roller bearings, in a steel sleeve. The question is often asked, is there not a tendency for these yokes to spread with an extra heavy load? If you will notice that the lines of force passing through the wheels meet at the bottom of the eye—where the load is suspended—it will be seen that the sides of the yokes are paralleled with these lines of force, and the chance of spreading is thus done away with.

These trolleys for a ton-load require but a 30-pound pull to operate, and have been tested time and again and found to be the easiest running, and require less keep-up of any design now made.

Switches are made to connect with two or three rails; they are provided with safety stops which effectively close all ends of the rails, and are operated by pendant handles. The only parts of the switch made of cast iron are the hand wheel and bearing wheels, the balance of the switch being steel forgings.

Fig. 1 shows these switches on an overhead tramrail system in a bedstead foundry.

Switches having cast iron gurads, and hinges are to be avoided on account of the liability of breakage, and consequent accident. During the ten years this design of switch has been used, no report of an accident has ever been made. The switches are easily operated.

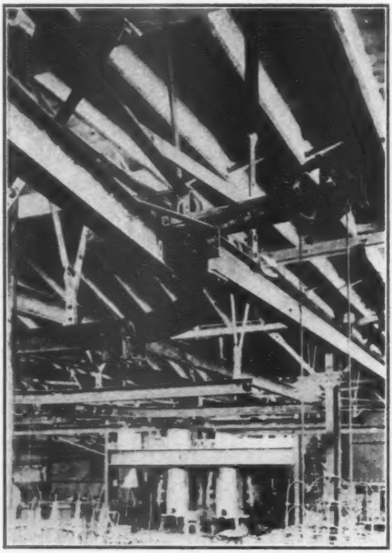

FIG. 1.

A pull on each of the hand chains throws the tongue to the required position, and once thrown the switch locks itself in position, and the tongue cannot move until the opposite hand chain is pulled.

It sometimes becomes necessary for the two rails to cross at right angles: in such a case a "cross-over" is used. A pull on the hand chain throws one hinged tongue up—a pull on the other hand chain throws the other hinged piece down, and the crossing is effected. Suitable guards working

automatically are provided, which effectively close all open rails.

Turn tables—connecting two, three or four rails are a necessity in some installations. On this machine two heavy cast bearing plates are used. The lower one is bolted down to the top flanges of the I-beam rail. The upper plate revolves on steel rollers. All open ends of the rails are guarded by steel forged angle guards, which operate automatically.

A gravity lock is provided, which is thrown out by a slight pull before pulling down on the handle, which throws the turn table.

Bearing in mind that for foundry use switches, turntables and cross-overs, must be operated quickly, and must be absolutely safe, these machines are designed, and built in a way which for want of a better word may be termed "fool-proof."

Where it is required to raise or lower a full load on the rail, an extension trolley hoist is used. By means of this hoist, the hand chains are kept away from the heat of the metal, and the man pushing the load easily operates the chain hoist. The forgoing may be taken as a brief description of the separate parts of a complete system.

EQUIPMENT FOR AVERAGE FOUNDRY.

We come now to the proper lay-out for the average foundry. A line of rail should extend down through the yard where pig, coke and scrap are stored, and this line run on to the elevator, where a short section of the rail is fastened to the elevator head, and a loop around in front of the cupola door—on the charging platform. By means of this lay-out loads of pig, coke and scrap may be carried on the tramrail from the yard on to the elevator, and off on the charging platform.

Fig. 2 shows a tramrail over the stockyard.

Fig. 3 illustrates the breaking of scrap with the lifting magnet.

FIG. 2.

FIG 3

Fig. 4 shows tramrail for carrying coke.

It should be remembered that from 250 to 500 pounds of coke, 500 to 1,000 pounds of scrap and up to a ton of pig

is carried at one load from the yard to the charging platform and dumped into the door of the cupola.

Contrasting this method with the old way of carrying the charge on a car on an industrial or narrow guage railway —with from two to four men—a considerable saving in labor will be apparent.

Too much attention cannot be given to the proper lay-out of the rails in front of the cupola, so that the hot metal may be moved as quickly as possible without interrup-

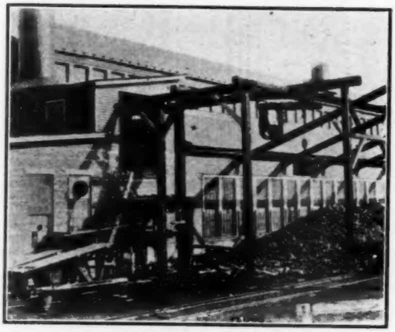

FIG. 4.

tion. In some plants a single rail may be used, but in this case a full load cannot pass an empty coming towards the cupola, and the spout must be plugged after each ladle is filled.

Fig. 5 illustrates the charging of coke into the cupola and Fig. 6 similarly the charging of scrap.

Fig. 7 shows flasks being transported in a bedstead foundry.

The question is often asked as to what is the proper height to place a tramrail from the ground. Many different heights, have been tried at different plants with varying degrees of efficiency. It has been found that a distance of

eight feet from the ground to the underside of the rail will enable a man to push a load of one ton with the least effort.

In one plant using tramrails the rail was placed at a height of 16 feet contrary to the advice of the manufacturer of the system. It was found that two men were necessary to convey the ton loads. This height was used for two years, and finally the system was taken down, and the hangers were lengthened, and the system re-erected at the height

FIG. 5.

of nine feet, when but one man was required to propel the ton loads. This made a saving of seven men a day—a very considerable yearly saving.

When the rail is placed higher than eight feet the suspending rod hanging from the trolley, swings back and forth as a pendulum when the push is applied, and the trolley instead of moving smoothly along the rail jumps forward with the consequent danger of slopping metal.

ERECTING THE EQUIPMENT.

To save as much original cost as possible in the purchase of a tramrail system, the customer should do his own erecting. Many systems are sold at a considerable distance from the manufacturer's plant, and to do away with the railroad fare, and expenses of an erector, it is necessary that the system be designed along simple lines, and that each piece be marked or numbered, and an erecting plan furnished with the shipment, showing the position of each piece of the system.

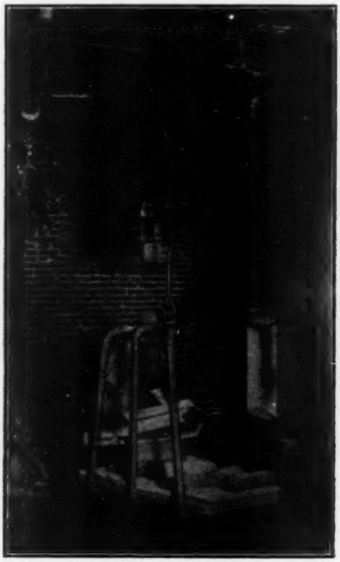

FIG 6.

The reduction of the cost of a system to the customer is an ever present desire with the maker, and hundreds of these systems, thus marked, and numbered, have been erected during the last ten years, by the foundrymen's own mechanics.

Fig. 8 shows a use for tramrail, which saves a considerable sum of money, that of handling cores. We have here

a picture of a section of a modern core-room, showing racks made of pipe for the storage of cores. A section of tramrail extends down in front of these racks, and by means of a switch, connects to the main rail running the length of the foundry. On the rail is a rack hung on trolleys.

These racks are filled in the core rooms, and run out over the main system to the floors. Springs are placed between the trolleys and the racks so as to take up any possible jar. The most delicate cores are handled in this way without breakage.

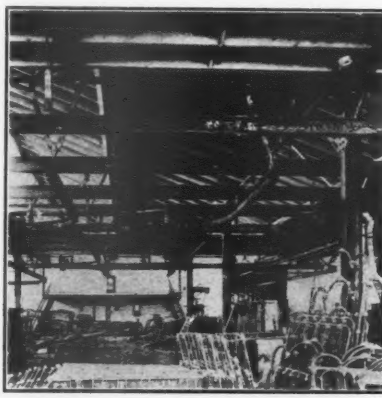

FIG. 7

After the rack is filled it is shoved out to the floors, and the required quantity of cores distributed in turn to each molder. A few figures on this method of carrying cores may be of interest. The picture here is a portion of a system which cost the foundry using it $1,000. Prior to the installation of the tramrail five men at $1.65 a day were employed carrying cores, at a total cost of $2,475.

After the installation, one man with the tramrail, distributed all the cores for the one hundred and twelve molders, at an expense of $495, or a saving of nearly $2,000 annually.

Bearing in mind the system cost but $1,000, that particular foundry had its original investment returned to it every six months of its business life.

A considerable saving may be effected by running a spur of the tramrail out to the sand bins, and by one man bringing in a bucket load of 1,000 pounds of sand. Running this over the main system, he can shovel out the necessary quantity of sand to the molders as he passes along, or he can dump the whole load when it is needed. This is shown in Fig. 9. Please bear in mind that by this method a thousand pounds of sand are carried as against the two, or three hundred pound wheel barrow load.

FIG. 8

A tramrail system is used in connection with a gravity molding machine, with four runs of rails in many foundries. A trolley on each rail, with a chain hoist takes the flasks away from the machine as quickly as the molds are made. No matter how many molds a machine can make an hour, unless these molds are carried away, as fast as they can be made, the greatest efficiency is not obtained.

Traveling, and jib cranes, have been tried out in use with the gravity molding machine, but it has been found

by tests that tramrail will carry away more flasks per hour, with less jarring than any other method yet devised.

Fig. 10 shows castings being loaded into the rumblers. The castings ready to be tumbled are loaded into dumping buckets, and are run into the rumbler rooms, and dumped direct into the rumblers. A ton of castings may thus be carried, though it has been found to be best practice to have the dump buckets the same capacity of the rumbler, or half the capacity, so that it takes a certain number of bucket loads to fill a certain number of rumblers.

FIG 9.

AN EASY PAY-ROLL METHOD.

Probably one of the most important uses to which tramrails are put, is in the method of paying the workman. In the majority of foundries the men are paid either by the day or by the piece. Every foundryman is familiar with

the many disputes that constantly arise between the man who does the work and the man who counts it. If the workman is paid by weight, these mistakes, discussions and disputes are entirely eliminated. With the exception of the molder, every foundry employe can be paid at a pound rate.

Nearly all of the finished product is sold at a pound price, and it would be of great benefit to the cost department to know what the rumbling, grinding and other finishing operations cost per pound.

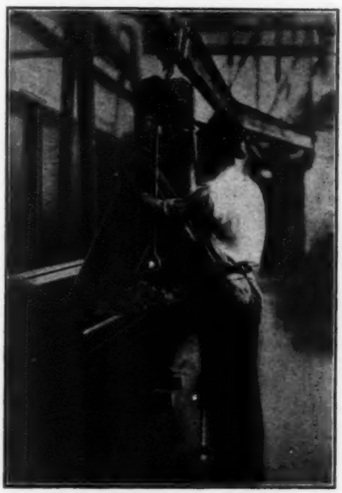

FIG. 10

This result can be readily obtained by means of a tramrail system in which has been installed at certain points, tramrail scales.

Let us assume that in the rumbling and grinding room a scale is placed, and when these two operations are finished, the castings are weighed, and the man who does the work is given a ticket with the weight and rate entered thereon.

A duplicate of this ticket is turned in to the time-keeper who, after making the proper entry, passes it on to the cost-keeper. The scales conveniently placed will record the exact weight of each operation.

The scales are attached to a section of the rail which is so arranged that the load is weighed as it passes along. The necessity of lifting the load off the rail and onto a floor scale is entirely done away with. The majority of floor scales, with the working parts sunk in pits are unfit for foundry use as sand and dirt soon work down into the operating pit and cut into the working parts of the scale. With a tram-

FIG. 11.

rail scale this cannot happen as all of the scale parts are up in the air out of the dust and dirt.

Fig. 11 shows such a scale.

HANDLING OF SOIL-PIPE.

In the making of the soil-pipe many molds are lost by reason of the metal in the small hand ladles not being uniform in temperature, when poured. The better way is to pour from tramrail, and when this is done an oblong ladle is used having four spouts so that the metal as it enters the pipes is of absolutely the same temperature.

Figs. 12 and 13 show the handling of Radiator Section and Fittings by overhead rail. Figs. 14 and 15 show the use of the overhead rail for the workhouse and in leading cars.

FIG. 12.

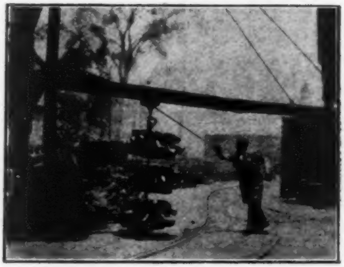

FIG. 13.

FLAT-RAIL TRAM.

There have been many arguments presented from time to time in favor of a flat rail tramrail. So this talk would hardly be complete without reference to flat rail installations. It may be said in favor of flat rail that where hangers are short, and suitable timbers can be found to which to fasten, a flat rail system is less expensive than an I-beam system.

But, as it is necessary to have timbers every four feet, as there must, for strength, be a hanger every four feet, this condition is so seldom met, as to practically throw a flat rail system out of consideration for foundry use. Some installations have been made in foundries where for every foot of flat rail, a foot of timber was erected to which to fasten the hangers every four feet.

FIG. 14

But, if you will add the cost of the timber to the cost of the flat rail system, not forgetting to add in the double erecting cost of the timber and the rail, it will readily be seen that a flat rail, or any system wherein the hangers have to be spaced, will be far in excess of an I-beam tramrail.

MAN VERSUS TRAMRAIL.

To sum up the whole subject, let us consider that one man with a wheelbarrow can handle 300 pounds; with a

floor truck over a wooden or cement floor, 1,000 pounds; over a foundry floor, 500 pounds; with an industrial track in a foundry when the tracks are in their usual condition, 1,000 pounds.

With a tramrail, one man can always push a load of 2,000 pounds. Therefore one man and a tramrail equals nearly seven men with wheelbarrows; four men with floor trucks and two men with an industrial truck.

Computed in manloads, the assertion made that a tramrail will return its first cost each year, can be readily computed in dollars and cents.

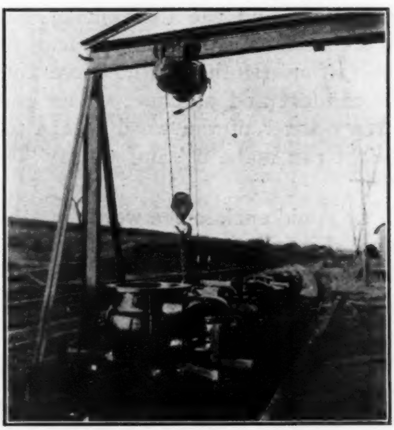

FIG. 15.

The meeting then adjourned until 10 A. M. Friday, June 10th.

LADIES' ENTERTAINMENT

While the members were busily engaged at the Session listening to and taking part in the discussions of the papers presented, their "Better Halves" were enjoying an Automobile Sight-Seeing Trip through Detroit. This was followed

by an elaborate luncheon at the Yacht Club, effectively removing all semblance of an appetite for dinner later on with the "Lesser Halves."

What the good Ladies who graced our Detroit Convention must have felt toward their charming sisters of the Detroit Ladies' Committee, was happily voiced by Mrs. H. N. Spencer, who at the close of the luncheon above specified, delivered the following extempore remarks which we were happy to catch in time for permanent record in our *Transactions*.

"Friends: As this ideal day nears the hour when it becomes past history, and the Convention which we have enjoyed closes its sessions, we turn with happy faces to the Sisters, and chivalrous Brothers, who have anticipated our every need for comfort and pleasure, whose guests we have been, 'where *every* letter of the word means to us *all* that heart and thought can make it,' and we say 'Thank You.' "

"We wish we could enclose the words in a halo of appreciation that may shine down the ages with golden memories, to reward you for your mission of love. We have found the minutest detail worked out to a degree of perfection that only such warm-hearted folk could, and every one of us, I feel sure, would make *this* wish for each one of you, Mrs. Henry and your chosen life companion, and your efficient co-laborers of the Committee. The wish would be that in your path through life you may find every loving thought surround you, and like the rose petals of June, create for you a wilderness of bloom, fragrant as the dew and sunshine can make them.

"We will carry with us, as we separate and walk the path our life holds for us, memories of happy greetings, and new made friends, that will be as scintillating gems in our casket of treasures, and with warmest feelings of sincere appreciation from the depths of our hearts, we again say 'Thank You.' "

SIXTH SESSION

Friday, June 10th, 10 A. M.

President Waterfall called the meeting to order, and asked for the presentation of Unfinished Business.

The Secretary reported the receipt of a letter of acknowledgement to the telegram sent during the first session in behalf of Dr. Holmes, from Secretary Ballinger, stating that the matter would be given due consideration.

The Secretary next presented an interesting communication from Mr. Geo. K. Hooper, in reply to a letter sent him asking for a paper on "Continuous Core Conveyors." Mr. Hooper unfortunately found himself unable to comply at the time, but sent the letter presented herewith, which should prove highly interesting to those foundrymen who may be similarly placed.

NEW YORK, April 28, 1910.

DR. RICHARD MOLDENKE,
Watchung, N. J.

DEAR DR. MOLDENKE:

Yours of the 25th has been waiting my return from several days absence. I find I shall be entirely unable to come to Detroit this year, as we are just starting up the large Symington malleable plant in Rochester and I am naturally very much occupied in getting all of the handling apparatus running.

Nearly everything there is being handled mechanically, coal to the furnaces, core sand to the core department, cores from the core makers to the ovens and thence to the storage racks, molding sand to and from the molding machines, molds from the molding machines to the floors and again to the

shaking-out grating, annealing scale from the stacks into bins to be dropped again into fresh stacks and coal also to the dust fuel burners at the annealing ovens. These are all starting with a fair degree of success.

Concerning the continuous core conveyor, which carries cores from the core maker to the ovens and thence to the storage racks handling also core driers and boxes back from ovens and storage racks to the core benches, would say that this started off from the first as a successful device and has operated without a hitch.

There are some trifling changes to be made in it to add steadiness to its operation, but it is carrying cores now and breaks fewer fresh cores between the benches and the ovens than are broken in handling baked cores from the ovens to the storage racks and out to the floors.

A little difficulty has been experienced by the settling of long cores, but I find that this is somewhat a matter of workmanship in making the cores, as cores that are carefully rammed do not show this difficulty.

The carriages travel at a speed of about 23 feet per minute which is sufficient for all handling purposes, and at that speed have a capacity sufficient to handle about 30,000 cores per ten-hour day through seven operations.

The owners are much pleased with the device as it is, but we shall, of course, make some small improvements in detail which I think will improve it mechanically.

The continuous type of core oven developed to operate with this carrier has proven to be a considerable success; also there is absolutely no machinery connected with it. A battery of seven is required with this particular installation and these are fired by oil and are operating with entire satisfaction.

I am sorry that I shall not be able to get to the Convention, but you are at liberty to use this letter as you may choose.

With personal regards, believe me,

Yours sincerely,

GEO. K. HOOPER.

The Secretary then presented a communication from Mr. Geo. C. Davis in which attention is called to the frequent occurrence of an undue amount of moisture in foundry coke, and suggesting that this be given attention by the membership. The amounts on occasion ran all the way up to fourteen per cent. The samples in question had been partially crushed and hence probably had lost some of the moisture before Mr. Davis received them for analysis.

President Waterfall. "I will now call for the report of the nominating committee.

Mr. McFadden. "Mr. Chairman and Gentlemen: Your nominating Committee recommend the following names for officers for the ensuing year."

For President, Joseph T. Speer, Pittsburgh Valve, Foundry & Foundry Construction Company, Pittsburgh, Pa.

For *Vice-President, 1st District,* F. B. Farnsworth, McLagon Foundry Company, New Haven, Conn.

For *Vice-President, 2nd District,* Walter Wood, R. D. Wood & Co., Camden, N. J.

For *Vice-President, 3rd District,* W. A. Bole, Westinghouse Machine Company, E. Pittsburgh, Pa.

For *Vice-President, 4th District,* Wm. Gilbert, Buckeye Foundry Company, Cincinnati, O.

For *Vice-President, 5th District,* J. W. Wilson, General Motors Company, Detroit, Mich

For *Vice-President, 6th District,* T. W. Sheriff, Sheriff's Manufacturing Company, Milwaukee, Wis.

For *Vice-President, 7th District,* Alfred E. Howell, Phillips & Buttorf Manufacturing Company, Nashville, Tenn.

For *Vice-President, 8th District,* A. N. W. Clare, Clare Stove Company Limited, Preston, Ont.

For *Secretary-Treasurer,* Richard Moldenke, Watchung, N. J.

The report is signed by the nominating committee.

Mr. Seaman. "I move the report of the committee be received, and if there are no other names presented, I move our secretary cast a ballot for the same, in order to save time."

The motion being duly supported and put, the same prevailed.

Secretary Moldenke. "The ballot is cast for the officers presented by the nominating committee."

President Waterfall. "We will now open under the head of New Business. Is there any new business to come before the meeting?"

Mr. McFadden. "Mr. President and Gentlemen: The duties of the Secretary have become so great that it is the consensus of opinion that a committee should be appointed to secure papers and properly edit them for the conventions. I therefore beg to move the following:

> *Resolved,* "that a committee composed of five members act in connection with the secretary, the duties of such a committee to be, to secure and edit papers, to be presented at future convention of the Association."

Secretary Moldenke. "This idea is a little new to me, but I am delighted to have such a motion brought before the house. Our trade papers are very liberal and can afford to get the best people to write articles for them. Now when

you get around to asking for papers for the convention gratuitously and ask men to get up a paper and give the time and effort of its preparation and the expense of the presentation before the convention, it is quite another thing."

The motion having been duly supported and put the measure prevailed.

Mr. McFadden. "I have another resolution.

> "*Resolved,* that a committee consisting of two be appointed for the purpose of auditing the books of the association. There will be two years to audit, by the way."

The resolution having been supported and submitted to the convention the same was carried.

Secretary Moldenke. "I would like to say at this time that the auditing committee will get the books in typewritten form."

Mr. McFadden. "I do not want to occupy the floor but I have another resolution that I think is appropriate and fitting.

> "*Whereas:* It is unanimously conceded that the Detroit Convention has been a perfect success, which success has resulted from the untiring efforts of the Detroit Local Convention Committee, and

> "*Whereas:* It is the desire of the American Foundrymen's Association as a whole that the appreciation of the Detroit Convention Committee should appear on the records of this Association, therefore be it

> "*Resolved,* that the American Foundrymen's Association tender to the entire Detroit Convention Committee, Chairmen of the various Committees, the ladies of the Reception Committee,

who have done so much to entertain the visiting ladies, and succeeded so well, in fact to all those who have worked so faithfully to make the convention the success it has been, their unanimous thanks and deep appreciation as shown by the action of this assembly.

"*Resolved* that this resolution be spread upon the records of the Association."

The resolution having been properly seconded and submitted to the assembly the same prevailed.

Mr. McFadden. "I have one more resolution I would like to offer, gentlemen, that is entirely in keeping with this.

"*Resolved* that the American Foundrymen's Association tenders to the officers of the Michigan State Fair Association, their thanks for the courtesies extended to the Detroit Foundrymen's Local Committee and to the officers and members of the Allied Foundrymen's Association for the use of the grounds, buildings, etc., during the convention of the Allied Foundrymen's Association, and that copy of such resolution be suitably engrossed and transmitted to the Secretary of the Michigan State Fair Association."

The resolution having been duly supported and put before the convention, the same was carried.

President Waterfall. "Any further business to come before the meeting?"

Mr. Seaman. "I ask that our new president take the chair for a few minutes."

The president-elect, Mr. Speer, assumed the chair and said:

"Gentlemen, I know it is customary upon taking the chair to thank you. My friends who know me know that I

am no talker. I sincerely appreciate the honor you have conferred upon me and I can only say that I will try to follow in the footsteps of my predecessor, and if I make any mistakes I want you to think it is from the head and not from the heart. I cannot say anything more to you except I thank you." (Applause.)

Mr. Seaman. "Mr. President and gentlemen, I suppose you all know that I am one of the 'has beens' of this convention. It is some years since I acted in the capacity of president and I have been looking around at our convention and back to the time when I was in the chair, and I have noticed that the duties that have devolved upon our retiring president are vastly heavier in comparison, with the duties that devolved upon me, and I rise for the purpose of thanking our late president and offering a resolution which I have had the pleasure of introducing at the different conventions for years past. The resolution is as follows:

> "*Whereas*: It has been customary to elect as an honorable member, the president of this association and as our retiring president has been so faithful in the performance of his duties, I move he be elected as an honorary member of this association."

Mr. McFadden. "I take great pleasure in seconding that motion."

Election unanimous. (Applause.)

Mr. Waterfall. "I am very proud to receive the honorary office that has been given me, I am sure that I appreciate the honor."

The President. "Is there any further business to come before the meeting?"

Mr. Field. "I move that a special vote of thanks be extended to the representatives of the press for their courtesy

and their efficiency in reporting these meetings and also for getting the programs for our meeting so correctly."

The motion having been duly supported and put to the convention, the same was carried.

President Speer. "It was my pleasure last year at the convention at Cincinnati to extend to the convention an invitation to visit Pittsburg in 1911. It is not necessary for me at this time to say what we have in Pittsburg, if I did I would have to mention some unpleasant subjects that I have in my mind's eye, but I can tell you now, that we have got our second sight (political sight), and I think it will be safe for you to accept the invitation and we will try to do the best we can for you. We have made some little preliminary arrangement and we want to try and get you there not only to give you all the pleasure we possibly can, but we will try to interest you in the papers that will come before the convention." (Applause.)

Mr. Field. "I move that this matter be referred to the executive committee as per the constitution with the recommendation that the convention be sent to Pittsburg next year."

The motion was duly supported.

Mr. Seaman. "I think the convention, itself, has more power than the executive committee in a matter of this kind."

Mr. Field. "You cannot set aside the constitution. The constitution so provides."

Mr. Seaman. "I will agree with Mr. Field in that regard, but it has been customary in the last few years for the convention to take that matter up. When you undertake to prepare for a convention of this kind, the time is very short, a year only, as undoubtedly Mr. Waterfall knows, and if we go out from this convention and inform the people

that it will be held in Pittsburg next year they will all know it and work for the necessary preparations."

Mr. McFadden. "I think it is the work of the executive committee to carry out the wishes of the convention."

Mr. Field. "I withdraw my motion."

Secretary Moldenke. "We know what the vote of the executive board will be upon the subject. We have several of them here and we can settle it in five minutes."

Mr. McFadden. "I move that this assemblage instruct the executive officers of the association to hold the next convention at Pittsburg."

The motion having been supported and put to the convention, the same prevailed.

President Speer. "It seems to me, since Pittsburg has got the convention, we are looking a little too far ahead. You know as well as I do that our business meeting, the most important meeting, is always the last. I believe that it would be wise for those cities that wish to have the convention to go to work exactly on the lines that Pittsburg did. What I mean to say is that they send their delegates to the meeting and let them come here and let us fight it out. It will make it so much more interesting. You don't want to lag, you want to go ahead, that is my idea."

Mr. McFadden. "I would ask that we have a copy of our constitution and by-laws published and sent to every registered member of this association. I don't think there are many copies in existence today, and we are transacting business more or less in the dark. I would like to offer a resolution to the effect, before we adjourn, that a copy of our constitution and by-laws be submitted to the executive committee that is coming in and if they meet their approval that a number of copies necessary to the requirements be printed and sent to the membership.

"We are not taking any power from the executive committee but we are just taking action here by which the association members are instructing the executive committee coming in how to apply their powers, and that they take action under our instructions."

The motion having been duly supported and submitted to the assemblage, the same was carried.

Mr. Field. "Would it not be well to have a list of the membership published and sent out with the constitution? We have not had a membership published since 1906 and I think it would be about time for a revised list. I so move."

Secretary Moldenke. "The list published in 1906 was the last one but at every convention that we have had, a stack of these lists, giving the constitution and by-laws was on hand. It is too expensive a job to do every year, as it runs from $150.00 to $175.00."

The motion being duly supported was submitted to the association and the same prevailed.

Upon motion the convention here adjourned.

TO WHOM IT MAY CONCERN

Your Secretary begs to call attention to an extract of a letter received from one of our valued members, to wit: "I notice quite often—in advertising matter, extracts—and sometimes these extracts are quite lengthy—from papers which have been prepared for and read at the American Foundrymen's Association meetings, without giving credit to either writer or the Association. While I recognize that all of the matter presented at our meetings is intended for public distribution, I do think that when thus used, at least the author, if not the Association, should receive due credit."

The above is respectfully submitted to the kindly attention on the part of Publicity Managers of our vigorous business enterprises, who do not stop to think that the man who gives his brains to the public should at least receive a little courtesy in return where the information imparted is used for a business advantage.

PIG IRON

Grades Gross Tons	1900	1901	1902	1903
Bess. and low Phos.	7,979,327	9,596,793	10,393,168	9,989,908
Basic (mineral fuel)	1,072,376	1,448,850	2,038,590	2,040,726
Forge pig iron	793,092	639,454	833,093	783,016
Foundry and Ferro-sil.	3,376,445	3,548,718	3,851,276	4,409,023
Malleable Bessemer	173,413	256,532	311,458	473,781
Spiegeleisen	207,505	231,822	168,408	156,700
Ferro-manganese	48,472	59,639	44,526	35,961
White, mottled, direct castings, etc.	138,612	96,546	180,788	120,137
Totals	13,789,242	15,878,354	17,821,307	18,009,252

Some time ago we were the recipients of an inquiry from Dr. Brandt, Secretary of the German Foundrymen's Association, in which he requested information regarding the production of pig iron in the United States.

Mr. A. I. Findley, Editor of *The Iron Age*, and one of our old and valued members, was good enough to compile the statement in question for Dr. Brandt, and favored us with a copy, which we give herewith as highly interesting to our members.

STATISTICS

Courtesy *The Iron Age*

1904	1905	1906	1907	1908	1909
9,098,659	12,407,116	13,840,518	13,231,620	7,216,976	10,557,370
2,483,104	4,105,179	5,018,674	5,375,219	4,010,144	8,250,225
550,836	727,817	597,420	883,167	457,164	725,624
3,827,229	4,758,038	4,773,011	5,151,209	3,637,622	5,322,415
263,529	635,236	699,701	920,290	414,957	658,048
162,370	227,797	244,980	283,430	111,376	142,831
57,076	62,186	55,520	55,918	40,642	82,209
54,230	69,011	77,367	80,308	47,137	56,749
16,497,033	22,992,380	25,307,191	25,781,361	15,936,018	25,795,471

The item Foundry and Ferrosilicon, with nearly five and one half millions of tons production in 1909 shows what an enormous quantity of metal goes through the cupola, particularly as with it goes at least one fifth the quantity in the shape of scrap.

The further item of Malleable Bessemer indicates the extent of the malleable casting industry. Here also we can add about 50% for sprues, or nearly a million of tons of metal melted in 1909.

No wonder that the Foundry Industry of the United States is the greatest in the world.

BOOK NOTICES

ENGINEERING CHEMISTRY, by Prof. Thos. B. Stillman, of Stevens Institute. Published by Chemical Publishing Co., Easton, Pa.

It gives us particular pleasure to present this substantial volume, written by one of our members, to the Foundry Industry. Now in its fourth edition, copiously illustrated, it should be found in the library of every foundry laboratory as well as the office of managers who have to do with the testing of materials they buy or sell.

The book is well written, strictly up-to-date—we observe our own Specifications in it—and perhaps we can do no better than to mention a few of the most interesting things to be found between its covers. Here they are: Data, analyses and discussion of coke, coal, ores, slag; methods for chemical determinations and separation of the metals, etc. Feed water for boilers, gas analysis and calculations, sampling methods for ore, coal, etc. Foundry Chemistry, analyses of clays, fire sand, brick, alloys, oils, even soap. Paints, acetylene, etc., and last but not least, a most excellent index to find things with.

YEAR BOOK OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, 1910, published by the Society, and edited by its Secretary, Prof. Edgar Marburg. (University of Pennsylvania, Philadelphia.)

We have long waited for the publication of such a volume as this, it contains the Standard Specifications adopted by the Society, the list of its members, technical committees,

and information concerning the work of the American Society as well of the International Society for testing Materials.

The book has 308 pages—which argues well for the activity of this more recent association of experts from all our national societies.

It is intended that the year book shall be issued regularly, keeping the matter at issue up-to-date.

Every foundry should have this book, as hardly a day passes without having some question on the testing of materials come up. Our own members are responsible for the portion relating to Cast Iron.

Correspond with Secretary Marburg for further information.

HOW TO MAKE CONVERTER STEEL CASTINGS, by Arthur Simonson, The Penton Publishing Co., Cleveland, Ohio. Price 75 cents. This illustrated book of 40 pages will give the foundryman who contemplates going into the making of steel castings, information on the converter process now much used for this purpose. The six chapters give the whole subject in fair outline, and are well worth reading even if it is decided not to undertake the going into a somewhat overcrowded field.

IRON AND STEEL, by Hugh P. Tiemann. Published by McGraw-Hill Book Co., New York City. This is the Webster's Dictionary of the iron and steel industry. Prof. Howe was good enough to write the Introduction, which at once stamps the book as O.K. As a matter of fact, however, in looking over the list of co-laborators, we see the familiar names of some of our members. As a book of real worth, few can equal this, for the busy man as well as for him who writes and wishes to be correct in his designa-

tions. Every office in which iron products are discussed should have a copy. The name of many a forgotten process is seen in the pages of this remarkable little book of 354 pages, and everything connected with iron and steel, the foundry, blast furnace, coke oven, and all the materials used therein may be found defined and described here.

PRACTICAL ALLOYING, by J. F. Buchanan. Published by The Penton Publishing Co., Cleveland, O. Price $2.50. This book, practically a compilation, well arranged, of material which originally appeared in THE FOUNDRY and other journals, indicates that it is live matter. Those of our iron founders who have brass foundries also will do well to get a copy for their library, as many questions arise in regard to mixtures which may be found well answered in this work. Particular attention is given to Standard Alloys, and as the bulk of our work in this direction is coming to be the repetition, with more or less exactness, of certain standard mixtures, this is a subject of prime importance.

THE FOUNDRY DATA SHEETS. The Penton Publishing Co., Cleveland, O. Price $1.00. Our rapid life and the necessity of making every minute during business hours count, has led to the gathering of much information in tabloid form. Hence data sheets. In this case we have them for Foundry use. The enterprising journal in question has gathered a goodly bunch of these, and they are commended to the drafting room of foundries as well as the offices where much calculating and planning is done. We hope to see the collection grow in size and value as well, as only exact and reliable material belongs in a compilation of data sheets. A glance through the list assures one of the value of what has been so far issued.

SI

For Rapid Calculation in Silicon Determination of Cast Iron.

Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2
.0030	.1411	.0080	.3762	.0130	.6113	.0180	.8464	.0230	1.082
1	.1458	1	.3809	1	.6159	1	.8511	1	1.086
2	.1505	2	.3856	2	.6207	2	.8558	2	1.091
3	.1550	3	.3903	3	.6254	3	.8605	3	1.096
4	.1599	4	.3950	4	.6301	4	.8652	4	1.100
5	.1646	5	.3997	5	.6349	5	.8699	5	1.105
6	.1693	6	.4044	6	.6395	6	.8746	6	1.110
7	.1740	7	.4091	7	.6442	7	.8793	7	1.114
8	.1787	8	.4138	8	.6489	8	.8840	8	1.119
9	.1834	9	.4185	9	.6536	9	.8888	9	1.123
.0040	.1881	.0090	.4231	.0140	.6583	.0190	.8934	.0240	1.128
1	.1928	1	.4279	1	.6628	1	.8981	1	1.133
2	.1975	2	.4326	2	.6677	2	.9028	2	1.138
3	.2022	3	.4373	3	.6724	3	.9075	3	1.143
4	.2069	4	.4419	4	.6771	4	.9122	4	1.147
5	.2116	5	.4467	5	.6817	5	.9169	5	1.152
6	.2163	6	.4514	6	.6865	6	.9216	6	1.157
7	.2210	7	.4561	7	.6912	7	.9263	7	1.161
8	.2257	8	.4608	8	.6959	8	.9310	8	1.166
9	.2304	9	.4655	9	.7006	9	.9357	9	1.171
.0050	.2351	.0100	.4702	.0150	.7053	.0200	.9404	.0250	1.176
1	.2398	1	.4749	1	.7100	1	.9451	1	1.180
2	.2445	2	.4796	2	.7147	2	.9498	2	1.185
3	.2492	3	.4843	3	.7194	3	.9545	3	1.190
4	.2539	4	.4890	4	.7241	4	.9592	4	1.195
5	.2586	5	.4937	5	.7288	5	.9639	5	1.199
6	.2633	6	.4984	6	.7335	6	.9686	6	1.204
7	.2680	7	.5031	7	.7382	7	.9733	7	1.209
8	.2727	8	.5078	8	.7429	8	.9780	8	1.213
9	.2774	9	.5125	9	.7476	9	.9827	9	1.218
.0060	.2821	.0110	.5172	.0160	.7523	.0210	.9870	.0260	1.223
1	.2868	1	.5219	1	.7570	1	.9921	1	1.228
2	.2915	2	.5266	2	.7617	2	.9968	2	1.233
3	.2962	3	.5313	3	.7664	3	1.002	3	1.237
4	.3009	4	.5360	4	.7711	4	1.006	4	1.241
5	.3056	5	.5407	5	.7758	5	1.011	5	1.246
6	.3103	6	.5454	6	.7805	6	1.016	6	1.251
7	.3150	7	.5501	7	.7852	7	1.020	7	1.255
8	.3197	8	.5548	8	.7899	8	1.025	8	1.260
9	.3244	9	.5595	9	.7946	9	1.029	9	1.265
.0070	.3291	.0120	.5642	.0170	.7993	.0220	1.034	.0270	1.270
1	.3338	1	.5689	1	.8040	1	1.038	1	1.274
2	.3385	2	.5736	2	.8087	2	1.044	2	1.279
3	.3432	3	.5783	3	.8135	3	1.049	3	1.284
4	.3479	4	.5831	4	.8182	4	1.053	4	1.288
5	.3527	5	.5878	5	.8229	5	1.058	5	1.293
6	.3574	6	.5925	6	.8276	6	1.063	6	1.298
7	.3621	7	.5972	7	.8323	7	1.067	7	1.303
8	.3668	8	.6019	8	.8370	8	1.072	8	1.307
9	.3716	9	.6066	9	.8417	9	1.076	9	1.311

LICA TABLE — I GRAMME SAMP

Prepared by H. M. Johnquest, Ansonia, Conn.

Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2
.0280	1.317	.0330	1.551	.0380	1.787	.0430	2.023	.0480	2.257	.0530	2.492
1	1.321	1	1.556	1	1.792	1	2.027	1	2.262	1	2.497
2	1.326	2	1.563	2	1.796	2	2.031	2	2.267	2	2.502
3	1.330	3	1.566	3	1.801	3	2.036	3	2.271	3	2.506
4	1.335	4	1.570	4	1.805	4	2.039	4	2.276	4	2.511
5	1.340	5	1.575	5	1.808	5	2.045	5	2.280	5	2.516
6	1.345	6	1.579	6	1.815	6	2.050	6	2.285	6	2.520
7	1.350	7	1.585	7	1.819	7	2.055	7	2.289	7	2.525
8	1.354	8	1.589	8	1.824	8	2.059	8	2.294	8	2.530
9	1.358	9	1.594	9	1.829	9	2.064	9	2.299	9	2.535
.0290	1.363	.0340	1.599	.0390	1.834	.0440	2.069	.0490	2.304	.0540	2.539
1	1.368	1	1.603	1	1.839	1	2.074	1	2.309	1	2.544
2	1.373	2	1.608	2	1.843	2	2.078	2	2.313	2	2.549
3	1.378	3	1.613	3	1.848	3	2.083	3	2.318	3	2.553
4	1.382	4	1.617	4	1.853	4	2.087	4	2.323	4	2.558
5	1.387	5	1.622	5	1.857	5	2.092	5	2.328	5	2.563
6	1.392	6	1.627	6	1.862	6	2.097	6	2.331	6	2.567
7	1.397	7	1.632	7	1.867	7	2.102	7	2.337	7	2.572
8	1.401	8	1.636	8	1.871	8	2.107	8	2.342	8	2.577
9	1.406	9	1.641	9	1.876	9	2.111	9	2.347	9	2.582
.0300	1.410	.0350	1.646	.0400	1.881	.0450	2.116	.0500	2.351	.0550	2.586
1	1.415	1	1.651	1	1.886	1	2.121	1	2.356	1	2.591
2	1.420	2	1.655	2	1.890	2	2.125	2	2.360	2	2.596
3	1.425	3	1.659	3	1.895	3	2.130	3	2.365	3	2.600
4	1.429	4	1.663	4	1.899	4	2.135	4	2.370	4	2.605
5	1.434	5	1.669	5	1.904	5	2.139	5	2.374	5	2.610
6	1.439	6	1.674	6	1.909	6	2.144	6	2.379	6	2.614
7	1.443	7	1.679	7	1.914	7	2.149	7	2.384	7	2.619
8	1.448	8	1.683	8	1.918	8	2.154	8	2.389	8	2.624
9	1.453	9	1.688	9	1.923	9	2.159	9	2.393	9	2.629
.0310	1.458	.0360	1.693	.0410	1.928	.0460	2.163	.0510	2.398	.0560	2.633
1	1.462	1	1.697	1	1.933	1	2.168	1	2.403	1	2.638
2	1.467	2	1.702	2	1.937	2	2.172	2	2.407	2	2.643
3	1.472	3	1.707	3	1.942	3	2.177	3	2.412	3	2.647
4	1.476	4	1.712	4	1.947	4	2.182	4	2.417	4	2.652
5	1.481	5	1.716	5	1.951	5	2.186	5	2.422	5	2.657
6	1.486	6	1.721	6	1.956	6	2.191	6	2.426	6	2.661
7	1.491	7	1.726	7	1.961	7	2.195	7	2.431	7	2.666
8	1.495	8	1.730	8	1.965	8	2.200	8	2.436	8	2.671
9	1.500	9	1.735	9	1.970	9	2.205	9	2.440	9	2.675
.0320	1.505	.0370	1.740	.0420	1.975	.0470	2.210	.0520	2.445	.0570	2.680
1	1.509	1	1.744	1	1.980	1	2.215	1	2.450	1	2.685
2	1.515	2	1.749	2	1.985	2	2.219	2	2.454	2	2.690
3	1.519	3	1.754	3	1.989	3	2.225	3	2.459	3	2.694
4	1.523	4	1.758	4	1.994	4	2.229	4	2.464	4	2.699
5	1.528	5	1.763	5	1.999	5	2.234	5	2.469	5	2.704
6	1.532	6	1.769	6	2.003	6	2.238	6	2.473	6	2.708
7	1.538	7	1.773	7	2.008	7	2.243	7	2.478	7	2.713
8	1.542	8	1.777	8	2.013	8	2.248	8	2.483	8	2.718
9	1.547	9	1.782	9	2.017	9	2.252	9	2.488	9	2.723

MPLE

Weight of Ignited Residue Times 47.02 Equals Percentage of Silicon.

% SiO₂	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2	Wt.	% SiO_2
.492	.0580	2.727	.0630	2.962	.0680	3.197	.0730	3.432	.0780	3.668
497	1	2.732	1	2.967	1	3.202	1	3.437	1	3.672
502	2	2.737	2	2.972	2	3.207	2	3.442	2	3.677
506	3	2.741	3	2.976	3	3.211	3	3.447	3	3.682
511	4	2.746	4	2.981	4	3.216	4	3.451	4	3.686
516	5	2.751	5	2.985	5	3.221	5	3.456	5	3.691
520	6	2.755	6	2.991	6	3.226	6	3.461	6	3.696
525	7	2.760	7	2.995	7	3.230	7	3.465	7	3.701
530	8	2.765	8	2.999	8	3.235	8	3.470	8	3.705
535	9	2.769	9	3.005	9	3.241	9	3.475	9	3.710
539	.0590	2.774	.0640	3.009	.0690	3.244	.0740	3.479	.0790	3.716
544	1	2.779	1	3.014	1	3.249	1	3.484	1	3.719
549	2	2.784	2	3.019	2	3.254	2	3.489	2	3.724
553	3	2.788	3	3.023	3	3.259	3	3.494	3	3.729
558	4	2.793	4	3.028	4	3.263	4	3.497	4	3.733
563	5	2.798	5	3.033	5	3.268	5	3.503	5	3.737
567	6	2.802	6	3.037	6	3.273	6	3.508	6	3.741
572	7	2.807	7	3.042	7	3.277	7	3.513	7	3.748
577	8	2.812	8	3.047	8	3.282	8	3.517	8	3.753
582	9	2.817	9	3.052	9	3.287	9	3.522	9	3.758
586	.0600	2.821	.0650	3.056	.0700	3.291	.0750	3.527	.0800	3.762
591	1	2.826	1	3.062	1	3.296	1	3.531	1	3.766
596	2	2.831	2	3.066	2	3.301	2	3.536	2	3.771
600	3	2.835	3	3.070	3	3.306	3	3.540	3	3.775
605	4	2.840	4	3.074	4	3.311	4	3.545	4	3.780
610	5	2.845	5	3.079	5	3.315	5	3.550	5	3.785
614	6	2.849	6	3.084	6	3.320	6	3.555	6	3.790
619	7	2.854	7	3.090	7	3.324	7	3.559	7	3.794
624	8	2.859	8	3.094	8	3.329	8	3.564	8	3.799
629	9	2.864	9	3.099	9	3.334	9	3.569	9	3.804
633	.0610	2.868	.0660	3.103	.0710	3.338	.0760	3.574	.0810	3.809
638	1	2.873	1	3.108	1	3.342	1	3.578	1	3.813
643	2	2.878	2	3.113	2	3.347	2	3.583	2	3.818
647	3	2.882	3	3.117	3	3.353	3	3.588	3	3.823
652	4	2.887	4	3.122	4	3.358	4	3.592	4	3.827
657	5	2.892	5	3.127	5	3.362	5	3.597	5	3.832
661	6	2.896	6	3.132	6	3.367	6	3.602	6	3.837
666	7	2.901	7	3.136	7	3.371	7	3.606	7	3.842
671	8	2.906	8	3.141	8	3.375	8	3.611	8	3.847
675	9	2.911	9	3.146	9	3.380	9	3.616	9	3.851
680	.0620	2.915	.0670	3.150	.0720	3.385	.0770	3.621	.0820	3.856
685	1	2.920	1	3.155	1	3.389	1	3.625	1	3.860
690	2	2.925	2	3.160	2	3.394	2	3.630	2	3.865
694	3	2.929	3	3.164	3	3.400	3	3.636	3	3.869
699	4	2.934	4	3.169	4	3.404	4	3.639	4	3.874
704	5	2.939	5	3.174	5	3.409	5	3.644	5	3.879
708	6	2.942	6	3.179	6	3.414	6	3.649	6	3.884
713	7	2.948	7	3.183	7	3.418	7	3.654	7	3.889
718	8	2.953	8	3.188	8	3.423	8	3.658	8	3.893
723	9	2.958	9	3.193	9	3.428	9	3.663	9	3.899

AMERICAN FOUNDRYMEN'S ASSOCIATION

ORGANIZED, MAY 12, 1896

CONSTITUTION

AND

MEMBERSHIP LIST

OFFICE OF THE ASSOCIATION
"CASTLE ELSINORE"
WATCHUNG, N. J.

1911

CONVENTIONS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION

Philadelphia	1896
Detroit	1897
Cincinnati	1898
Pittsburgh	1899
Chicago	1900
Buffalo	1901
Boston	1902
Milwaukee	1903
Indianapolis	1904
New York	1905
Cleveland	1906
Philadelphia	1907
Toronto	1908
Cincinnati	1909
Detroit	1910
Pittsburgh (to be held May 22-26)	1911

CONSTITUTION OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION

ARTICLE I.

Name and Object.

Sec. 1. This Association shall be known as the American Foundrymen's Association.

Sec. 2. The objects of this Association shall be the advancement of the interests of foundry operators, or all who are concerned in the casting of any kind of metal in sand, or loam molds, for any purpose; to collect for use of the Association all proper information connected with the foundry business; to exchange experience and encourage uniform customs and actions among foundrymen.

ARTICLE II.

Membership

Sec. 1. The membership of this Association shall consist of three classes to be called respectively, active, associate, and honorary members.

Sec. 2. Any person, firm or corporation, engaged in the production of castings of any kind, as employer, superintendent, foreman, or chemist, may be elected an active member; and any associate member may become an active member when recommended by the Executive Board and approved by a majority vote of the Association at any regular meeting.

Sec. 3. Any person whose knowledge or services are valuable toward the objects of this Association, may be elected an associate member.

Sec. 4. Any individual whose knowledge or services, in connection with the objects of this Association, which have made him preeminent among his fellows, may be elected an honorary member.

ARTICLE III.

Sec. 1. The officers of this Association shall consist of a president, eight vice-presidents, a secretary, and a treasurer, who shall together form the Executive Board of this Association.

Sec. 2. The eight vice-presidents shall be elected from their respective districts as follows:

(1) New England States.

(2) New York and New Jersey.

(3) Pennsylvania, Delaware and Maryland and District of Columbia.

(4) Michigan, Ohio, Kentucky, and Tennessee.

(5) Indiana, Illinois, Missouri, Kansas, Colorado, New Mexico, Utah, Arizona, Nevada and California.

(6) Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Idaho, Nebraska, Montana, Wyoming, Washington, and Oregon.

(7) Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma and Texas.

(8) Provinces of Ontario and of Quebec, in the Dominion of Canada.

The vice-presidents shall elect one of their number as senior vice-president.

ARTICLE IV.

Sec. 1. There shall be an annual meeting of this Association during the month of May, the date and location of which shall be fixed by the Association at its regular annual

meeting; provided, that if no time and place are determined upon at the annual meeting the Executive Board shall fix the time and place at least three months in advance of the said meeting. Twenty-five members shall constitute a quorum of the Association.

Sec. 2. Meetings of the Executive Board may be called by the president or by any three members of said Board, and five members shall constitute a quorum,

ARTICLE V.

Sec. 1. This constitution may be amended at any regular meeting of the Association by a two-thirds vote of those present, provided the affirmative vote represents a majority of the members of this Association; and provided, also, that in case the required majority be not present, the Secretary shall, within 30 days after adjournment, submit the proposed amendment for letter ballot by mail.

BY-LAWS

Duties of Officers.

Sec. 1. The duties of the president shall be to preside at the meetings of the Association and of the Executive Board, and to perform such other duties as usually devolve upon a presiding officer.

Sec. 2. The senior vice-president shall perform the duties of the president when the latter is absent or unable to perform the same, or in case of vacancy in the office of the president.

Sec. 3. The duties of the secretary shall be to keep a full and accurate record of the proceedings of the Association

and Executive Board, to make an annual report at the annual meeting, showing the number of active, associate and honorary members of the Association, the amount of dues collected, and the orders issued on the treasurer, and he shall perform such other duties as may be assigned to him by the president or Executive Board.

Sec. 4. The duties of the treasurer shall be to take charge of all funds of the Association, and pay them out only upon the order of the secretary, countersigned by the president; he shall report at the annual meeting his receipts and disbursements for the year, in detail; he shall give a bond, the amount of which is to be fixed by the Executive Board.

Sec. 5. It shall be the duty of the Executive Board to manage the affairs of the Association to the best of their ability.

Membership

Sec. 6. All applications for membership shall be made to the Secretary.

Sec. 7. On the first day of each month the secretary shall mail to each member of the Executive Board a list of applicants for membership. If he shall not receive, by the 15th day of the same month, the written protest of two of the members of the Executive Board to any application, he shall then enroll the said applicants as members of the Association, and notify them at once of their election.

Dues

Sec. 8. The annual dues for each active or associate member of the Association shall be $10.00, which shall be due and payable annually in the month of July.

Sec. 9. No dues or assessments of any kind shall be collected from honorary members.

Elections

Sec. 10. All officers of the Association shall be elected by ballot by the active members of the Association at its annual meeting; a majority vote of those voting being necessary to elect.

Sec. 11. All officers of the Association shall hold office for one year from the adjournment of the annual meeting at which they are elected, and until their successors shall have been elected. In the case of a vacancy occurring in any office during the year, the Executive Board shall fill the vacancy for the unexpired term.

Order of Business

Sec. 12. The order of business to be observed at annaul meetings shall be as follows:

(1) Reading of the minutes of the last meeting.

(2) Announcement by the president of special committees, as follows:

A committee of five to nominate officers for the following year.

A committee of three to audit the accounts of the secretary and treasurer.

A committee of five to report on papers to be presented to the Association.

(3) Report of officers and standing committees.

(4) Report of special committees.

(5) Unfinished business.

(6) New business.

(7) Election of officers.

Amendments

Sec. 13. These by-laws may be amended at any regular meeting of the Association by a two-thirds vote of those present, provided the affirmative vote represents a majority of the members of the Association; and provided, also, that

in case the required majority be not present, the Secretary shall, within 30 days after adjournment, submit the proposed amendment for letter ballot by mail.

Rules of Order

Sec. 14. Roberts' Parliamentary Rules of Order shall be recognized as authority by this Association.

OFFICERS OF THE ASSOCIATION

1910—1911

President, JOSEPH T. SPEER,
Pittsburgh Valve, Foundry & Construction Co.
Box 1016, Pittsburgh, Pennsylvania.

Vice-President, First District, F. B. FARNSWORTH,
McLagon Foundry Co., New Haven, Conn.

Vice-President, Second District, WALTER WOOD,
R. D. Wood & Co., (Camden, N. J.) Philadelphia, Pa.

Vice-President, Third District, W. A. BOLE,
Westinghouse Machine Co., E. Pittsburgh, Pa.

Vice-President, Fourth District, WILLIAM GILBERT,
Buckeye Foundry Co., Cincinnati, Ohio

Vice-President, Fifth District, J. J. WILSON,
General Motors Co., Detroit, Mich.

Vice-President, Sixth District, T. W. SHERIFF,
Sheriff's Manufacturing Co., Milwaukee, Wis.

Vice-President, Seventh District, ALFRED E. HOWELL,
Phillips & Buttorf Manufacturing Co., Nashville, Tenn.

Vice-President, Eighth District, A. N. W. CLARE,
Clare Stove Co., Preston, Ont.

Secretary-Treasurer, RICHARD MOLDENKE,
Watchung, New Jersey.

COMMITTEES

AUDITING

Wm. Yagle
H. E. Field

PAPERS

H. E. Field, Chairman,
L. L. Anthes
Ellsworth M. Taylor
A. O. Backert

METALLURGY

H. E. Diller

INDUSTRIAL EDUCATION

P. Kreuzpointner

LIST OF MEMBERS

1896 Abendroth Brothers,
Port Chester, N. Y.

1907 Acme Foundry Co., The
Cleveland, O.

1908 Acme Steel & Malleable Iron Works,
Buffalo, N. Y.

1910 Adams Co., The,
Dubuque, Ia.

1900 Addy & Co., Matthew,
Pittsburgh, Pa.

1907 Adriance, Platt & Co.,
Poughkeepsie, N. Y.

1907 Advance Thresher Co.,
Battle Creek, Mich.

1896 Aermotor Co.,
Chicago, Ill.

1910 Aktieselskabet Tyssefaldene,
Kristiania, Norway.

1909 Alamo Iron Works,
San Antonio, Texas.

1908 Alamo Manufacturing Co., The,
Hillsdale, Mich.

1907 Aland, Charles M.,
Coshocton, O.

1907 Allen, Andrew, Jr.,
486 Greenwich St., New York City.

1908 Allen Co., Charles G.,
Barre, Mass.

1909 American Aquahoist Co.,
Winston-Salem, N. C.

1900 American & British Manufacturing Co.,
Providence, R. I.

1908 American Blower Co.,
Detroit, Mich.

1906 American Bridge Co.,
Ambridge, Pa.

1907 American Clay Machinery Co.,
Willoughby, O.

1910 American Hoist & Derrick Co.,
St. Paul, Minn.

1907 American Laundry Machinery Co.,
Rochester, N. Y.

1908 American Lumber Manufacturing Co.,
Pittsburgh, Pa.

1910 American Range & Foundry Co.,
Cleveland, O.

1909 American Rolling Mill Co.,
Middletown, O.

1907 American Saw Mill Machinery Co.,
Hackettstown, N. J.

1907 American Seeding Machine Co.,
Springfield, O.

1909 American Ship Windlass Co.,
Providence, R. I.

1906 American Steel Foundries,
Chicago, Ill.

1907 American Wood Working Machinery Co.,
Rochester, N. Y.

1908 Amherst Foundry Co., Ltd.,
Amherst, N. S.

1910 Anaconda Copper Mining Co.,
Anaconda, Mont.

1906 Anderson Axel,
129 Lafayette Ave., Buffalo, N. Y.

Anthes, L. L. Hon. Member,
Toronto, Ont.

1904 Anthes Foundry Co., Ltd.,
Toronto, Ont.

1904 Antisell, F. L., *Raritan Copper Works*,
Perth Amboy, N. J.

1907 Arcade Manufacturing Co.,
Freeport, Ill.

1904 Ayers Mineral Co.,
Zanesville, O.

1909 Babcock & Wilcox Co.,
Barberton, O.

1907 Backert, A. O., *Penton Publishing Co.*,
Cleveland, O.

1908 Baird & West,
Detroit, Mich.

1904 Baird Machinery Co., U.,
Pittsburgh, Pa.

1906 Baltimore Foundry Co.,
Baltimore, Md.

1906 Baltimore Malleable Iron & Steel Casting Co.,
Baltimore, Md.

1904 Barber-Whitely Coal & Coke Co.,
Pittsburgh, Pa.

1896 Barbour-Stockwell Co.,
Cambridgeport, Mass.

1907 Barnett Foundry Co., Oscar
Newark, N. J.

1908 Barnum, S. H.,
New Haven, Conn.

1908 Barstow Stove Co.,
Providence, R. I.

1908 Bartley Crucible Co., Jonathan,
Trenton, N. J.

1908 Bassett, G. P., Jr.,
Oliver Bldg., Pittsburgh, Pa.

1910 Bass Foundry & Machine Co., The,
Fort Wayne, Ind.

1909 Baxter Stove Co.,
Mansfield, O.

1909 Bay View Foundry Co.,
Sandusky, O.

1896 Beckett, James A.,
Hoosick Falls, N. Y.

1900 Beckwith, P. D., Estate of,
Dowagiac, Mich.

1907 Bell Co., The C. S.,
Hillsboro, O.

1907 Belle City Malleable Iron Co.,
Racine, Wis.

1908 Belleville Stove & Range Co.,
Belleville, Ill.

1908 Bement, C. E., *The Hildreth Mfg. Co.*,
Lansing, Mich.

1907 Berkshire Mfg. Co.,
Cleveland, O.

1908 Berlin Machine Works,
Beloit, Wis.

1907 Berryhill, John H., *Vulcan Plow Co.*,
Evansville, Ind.

1908 Bertram & Sons Co., Ltd., The John,
Dundas, Ont.

1896 Best, T. J.,
1693 St. Urbain St., Montreal, P. Q.

1907 BEST FOUNDRY CO., THE,
Bedford, O.

1897 BETHLEHEM FOUNDRY & MACHINE CO.,
South Bethlehem, Pa.

1905 BETHLEHEM STEEL CO.,
South Bethlehem, Pa.

1909 BETTENDORF J. W., PREST., *Bettendorf Axle Co.*,
Bettendorf, Ia.

1907 BINNS, E. L., *American Seeding Machine Co.*,
Springfield, O.

1909 BIRKENSTEIN & SONS, S.,
Chicago, Ill.

1896 BIRMINGHAM IRON FOUNDRY,
Derby, Conn.

1902 BLAIR & CO., REED F.,
Pittsburgh, Pa.

1907 BLUNDELL, FRED.,
Cleveland, O.

1903 BOOTH, GARRETT & BLAIR,
Philadelphia, Pa.

1908 BOWMANVILLE FOUNDRY CO. LTD., THE,
Bowmanville, Ont.

1908 BRACKEN, W. H.,
Hopedale, Mass.

1896 BRAYER., PREST., FRANK N., *Co-operative Foundry Co.*,
Rochester, N. Y.

1901 BRADDOCK MACHINERY & MANUFACTURING CO.,
Braddock, Pa.

1908 BRADLEY, DAVID, MANUFACTURING CO.,
Bradley, Ill.

1907 BRAKES, JAMES,
Lyon Mountain, N. Y.

1911 BRASSEUR, JULES.,
356 Avenue Louise, Brussels, Belgium.

1907 BRAUCHER, PETER S., *P. & R. Locomotive Shops Foundry*,
Reading, Pa.

1907 BRIAR HILL IRON & COAL CO.,
Youngstown, O.

1896 BROADWAY IRON FOUNDRY CO.,
Cambridgeport, Mass.

1907 BROMLEY, F. L., PREST., *American Motor Castings Co.*,
Detroit, Mich.

1908 BROOKLYN FOUNDRY CO.,
Brooklyn, N. Y.

1907 BROOKS, R. G., *International Harvester Co.*,
Chicago, Ill.

1903 BROWN, L. K.,
Zanesville, O.

BROWN, WILLIS, Hon. Member,
534 Main St., Buffalo, N. Y.

1906 BROWN, E. E. & Co.,
McKean & Meadow Sts., Philadelphia, Pa.

1896 Brown & Sharpe Manufacturing Co.,
Providence, R. I.

1909 Brown Specialty Machinery Co.,
Chicago, Ill.

1909 Browning Engineering Co.,
Cleveland, O.

1910 Buchanan, Judson, *Chattanooga Plow Co.*,
Chattanooga, Tenn.

1907 Buchanan Foundry Co., The,
Lebanon, Pa.

1907 Buch's Sons, A.,
Elizabethtown, Pa.

1907 Buckeye Engine Co.,
Salem, O.

1907 Buckeye Foundry Co., The,
Cincinnati, O.

1907 Bucyrus Co., The,
South Milwaukee, Wis.

1909 Bucyrus Steel Casting Co., The,
Bucyrus, O.

1905 Buffalo Foundry & Machine Co.,
Buffalo, N. Y.

1908 Buffalo Pitts Co.,
Buffalo, N. Y.

1907 Bull, R. A., *Commonwealth Steel Co.*,
Granite City, Ill.

1896 Bunker Hill Iron Foundry,
Charlestown, Mass.

1909 Burroughs Adding Machine Co.,
Detroit, Mich.

1910 Byram & Co.,
Detroit, Mich.

1907 Cahill Iron Works, The,
Chattanooga, Tenn.

1909 Caldwell, H. W., & Son Co.,
Chicago, Ill.

1908 Calumet Engineering Works,
Harvey, Ill.

1908 Cameron, A. S., Steam Pump Works,
New York City.

1910 Camp, E. N., & Sons Co., Inc.,
Moreland, Ga.

1903 Canada Iron Corporation, Ltd., The,
Midland, Ont.

1907 Canadian Locomotive Co., Ltd.,
Kingston, Ont.

1908 Canadian Machinery,
Toronto, Ont.

1910 Capital Casting Co.,
Lansing, Mich.

1907 Capitol Foundry Co., The,
Hartford, Conn.

1900 CARBORUNDUM CO., THE,
Niagara Falls, N. Y.

1900 CARONDELET FOUNDRY CO.,
St. Louis, Mo.

1904 CARR, STEWART, R., & CO.,
Baltimore, Md.

1908 CASE, J. I., PLOW CO.,
Racine, Wis.

1907 CAST THREAD FITTING & FOUNDRY CO., THE,
Seneca Falls, N. Y.

1908 CATCHINGS, WADDILL, *Central Foundry Co.*,
New York City.

1910 CENTRAL FOUNDRY CO. OF JACKSON,
Jackson, Mich.

1909 CENTRAL FOUNDRY SUPPLY CO.,
Columbus, O.

1909 CENTRAL IRON WORKS,
Quincy, Ill.

1910 CENTRAL RADIATOR CO.,
Lansdale, Pa.

1907 CENTRE FOUNDRY & MACHINE CO.,
Wheeling, W. Va.

1901 CHAIN BELT CO.,
Milwaukee, Wis.

1908 CHAPMAN, T. M., SONS & CO.,
Oldtown, Me.

1907 CHENEY, S., & SON,
Manlius, N. Y.

1910 CHESTER STEEL CASTING CO., THE,
Chester, Pa.

1907 CHICAGO HARDWARE FOUNDRY CO.,
North Chicago, Ill.

1907 CHICAGO PNEUMATIC TOOL CO.,
Chicago, Ill.

1908 CHISHOLM & MOORE MFG. CO., THE,
Cleveland, O.

1906 CITY FOUNDRY CO., THE,
Cleveland, O.

1908 CLARE BROS. & CO., LTD.,
Preston, Ont.

1907 CLARK IRON WORKS,
Philadelphia, Pa.

1908 CLARK BROS. CO.,
Belmont, N. Y.

1910 CLELAND, J. H.,
Meaford, Ont.

1907 CLEVELAND WIRE SPRING CO.,
Cleveland, O.

1900 CLINTON IRON & STEEL CO.,
Pittsburgh, Pa.

1908 COCKSHUTT PLOW CO.,
Brantford, Ont.

1910 COLBY, IRVING N.,
Granville, Ill.

1896 COLORADO FUEL & IRON CO.,
Pueblo, Col.

1897 COLORADO IRON WORKS CO.,
Denver, Co.

1907 COLUMBUS IRON & STEEL CO., THE
Columbus, O.

1907 COLUMBUS IRON WORKS,
Columbus, Ga.

1896 COLVIN FOUNDRY CO.,
Providence, R. I.

1909 COLWELL LEAD CO.,
Elizabeth, N. J.

1906 CONNERSVILLE BLOWER CO., THE
Connersville, Ind.

1907 CORBIN, P. & F.,
New Britain, Conn.

1909 COOSA PIPE & FOUNDRY CO.,
Gadsden, Ala.

1897 COX STOVE CO., ABRAM,
Philadelphia. Pa.

1896 CRANE CO.,
Chicago. Ill

1900 CRANE CO., WM. M.,
Jersey City, N. J.

1901 Crane Iron Works,
Catasauqua, Pa.

1910 Crescent Machine Co.,
Leetonia, O.

1907 Crowell & Murray,
Cleveland, O.

1908 Crozier, J. J.,
Kenneth Square, Pa.

1909 Cumberland Foundry & Machine Co.,
West Nashville, Tenn.

1908 Curtenius, D. R., *Kalamazoo Stove Co.*,
Kalamazoo, Mich.

1908 Curtis & Co. Mfg. Co.,
Wellston P. O., St. Louis, Mo.

1907 Cutter, Wood & Stevens Co.,
Boston, Mass.

1900 Damascus Bronze Co.,
Allegheny, Pa.

1910 Davenport & Keller,
New Britain, Conn.

1896 Davenport Machine & Foundry Co.,
Davenport, Ia.

1906 Davis, Geo. C.,
39 S. 10th St., Philadelphia, Pa.

1907 Davison-Namack Foundry Co.,
Ballston Spa, N. Y.

1898 Dawes & Miller,
New Brighton, Pa.

1910 Day-Ward Co., The.
Warren, O.

1907 Debevoise-Anderson Co.,
95 Liberty St , New York City.

1909 Deeley, Thos. E.,
541 West 32nd St., New York City.

1910 Deere & Co.,
Moline, Ill.

1908 Deeming Mfg. Co., The,
Salem, O.

1910 Demmler & Bros., Wm.,
Kewanee, Ill.

1907 Detroit Foundry Supply Co.,
Detroit, Mich.

1910 Detroit Hoist & Machine Works,
Detroit, Mich.

1906 Detroit Testing Laboratory, The,
Detroit, Mich.

1904 Devlin Mfg. Co., Thos.,
Philadelphia, Pa.

1907 Dewey Bros., Inc.,
Goldsboro, N. C.

1900 Diamond Clamp & Flask Co.,
Richmond, Ind.

1901 DILLER, H. E., *General Electric Co. Laboratories*,
Schenectady, N. Y.

1907 DINGS ELECTROMAGNETIC SEPARATOR CO.,
Milwaukee, Wis.

1896 DIXON CRUCIBLE CO., JOS.,
Jersey City, N. J.

1898 DODGE MANUFACTURING CO.,
Mishawaka, Ind.

1908 DODGE MANUFACTURING CO.,
Toronto, Ont.

1907 DOGGETT, STANLEY,
101 Beekman St., New York City.

1909 DOMVILLE, A. E.,
223 West 2nd St., Berwick, Pa.

1907 DOUGLAS, W. & B.,
Middletown, Conn.

1909 DOVER FIRE BRICK CO.,
Cleveland, O.

1909 DOWLER, A. S.,
Box 62, Brooklyn, Maryland.

1908 DOWN DRAFT FURNACE CO., LTD., THE,
Galt, Ont.

1906 DRUMMOND, E. M., Prest., *Drummond Mfg. Co.*,
Louisville, Ky.

1907 DUQUESNE STEEL FOUNDRY CO.,
Pittsburgh, Pa.

1909 EAGLE CASTING CO.,
Winchester, Ky.

1902 EATON, F. M., *Hickman, Williams & Co.*,
Cincinnati, O.

1910 EATON RAPIDS FOUNDRY CO.,
Eaton Rapids, Mich.

1906 ELMIRA FOUNDRY CO.,
Elmira, N. Y.

1905 EMERSON, HARRINGTON,
30 Church St., New York City.

1908 EMERSON, SAMUEL D. I.,
137 Corlies Ave., Pelham, N. Y.

1908 EMERSON LABORATORY,
177 State St., Springfield, Mass.

1904 ENGLAND, GEO., SUPT., *Edgar Thomson Foundries*,
Braddock, Pa.

1907 ENTERPRISE FOUNDRY CO.,
Detroit, Mich.

1908 ENTERPRISE FOUNDRY CO., THE,
Sackville, N. B.

1896 ENTERPRISE MFG. CO. OF PA., THE,
Third and Dauphin, Philadelphia, Pa.

1907 ENTERPRISE SAND CO.,
Pittsburgh, Pa.

1909 EPPING-CARPENTER CO.,
Pittsburgh, Pa.

1900 Erie Foundry Co.,
Erie, Pa.

1907 Estate Stove Co., The,
Hamilton, O.

1906 Eureka Foundry Co.,
Chattanooga, Tenn.

1907 Excelsior Stove & Mfg. Co.,
Quincy, Ill.

1907 Eynon-Evans Mfg Co.,
Philadelphia, Pa.

1910 Fairbanks, Morse & Co.,
Beloit, Wis.

1900 Falls Clutch & Machinery Co.,
Cuyahoga Falls. O.

1901 Farrel Foundry & Machine Co,,
Ansonia, Conn.

1910 Favorite Stove & Range Co., The,
Piqua, O.

1909 Fay, J. A. & Egan Co.,
Cincinnati, O.

1909 Feaser, Geo. A.,
South Bend, Ind.

1909 Federal Foundry Supply Co.,
Cleveland, O.

1910 Fell, Jos. E,
Ogdensburg, N. Y.

1910 FERGUSON & LANGE FOUNDRY CO.,
Chicago, Ill.

1899 FIELD, HERBERT E., *Mackintosh, Hemphill & Co.*,
Pittsburgh, Pa.

1910 FINDLAY BROS.,
Carlton Place, Ont.

1910 FISHER, SAMUEL H.,
2106 N. 6th St., Harrisburg, Pa.

FLAGG, STANLEY G., JR., HON. MEMBER,
1421 Chestnut St., Philadelphia, Pa.

1896 FLAGG & CO., STANLEY G.,
424 N. 19th St., Philadelphia, Pa.

1908 FLEMING, JAMES, *Phoenix Foundry*,
St. John, N. B.

1908 FLEURY'S SONS, J.,
Aurora, Ont.

1909 FOGARTY, W. J.,
74 Fountain Ave., Dayton, O.

1901 FORAN FOUNDRY & MFG. CO.,
Flemington, N. J.

1909 FORD, J. C., *Spring Lake Foundry Co.*,
Fruitsport, Mich.

1906 FT. PITT MALLEABLE IRON CO.,
McKees Rocks, Pa.

1909 FT. PITT STEEL CASTING CO.,
McKeesport, Pa.

1907 FOUNDRY SPECIALTY CO., THE,
Cincinnati, O.

1908 FOX'S SONS, BENJ.,
513 West 34th St., New York City.

1900 FRENCH & HECHT,
Davenport, Ia.

1900 FRENCH & HECHT,
Springfield, O.

1898 FRICK CO.,
Waynesboro, Franklin Co., Pa.

1901 FROHMAN, E. D., *The S. Obermayer Co.*,
Pittsburgh, Pa.

1906 FRIEDENWALD, H. W.,
Montford Ave., near Chase St., Baltimore, Md.

1904 FULLER, BENJ. D., *Westinghouse Electric & Mfg. Co.*,
Cleveland, O.

1909 FULLER, R. W.,
Scranton, Pa.

1907 FULLER & WARREN CO.,
Troy, N. Y.

1906 FULTON FOUNDRY & MACHINE CO.,
25 Furman St., Brooklyn, N. Y.

1907 GAIBLE, JULIAN, *The Brownell Co.*,
Dayton, O.

1909 GAINESVILLE IRON WORKS,
Gainsville, Ga.

1910 GALION IRON WORKS CO., THE,
Galion, O.

1908 GALT MALLEABLE IRON CO., LTD., MESSRS.,
Galt, Ont.

1896 GARDEN CITY SAND CO., THE,
Cleveland, O.

1907 GARDNER GOVERNOR CO., THE,
Quincy, Ill.

1908 GARDNER PRINTING CO., THE,
Cleveland, O.

1904 GARRISON FOUNDRY CO., A.,
Pittsburgh, Pa.

1897 GENERAL ELECTRIC CO.,
West Lynn, Mass.

1906 GENERAL ELECTRIC CO.,
Schenectady, N. Y.

1896 GENERAL FIRE EXTINGUISHER CO.,
Providence, R. I.

1896 GIBBY FOUNDRY CO.,
E. Boston, Mass.

1908 GIBNEY, JAMES W.,
416 Woodward Ave., Buffalo, N. Y.

1908 GILBERT, GEO. McA.,
Carthage, N. Y.

1910 GILBERT, L. D.,
King St., Waynesboro, Pa.

1909 Gill, J. H.,
Raleigh, N. C.

1908 Gill, John M., *Jas. Smart Mfg. Co.*,
Brockville, Ont.

1900 Gilmour, Edw. B.,
2 Conduit St., Toronto, Ont.

1903 Gilson Mfg. Co.,
Port Washington, Wis.

1909 Girard Iron Co., The
Girard, Trumbull Co., Ohio.

1907 Girard Iron Works,
22nd & Master Sts., Philadelphia, Pa.

1907 Gleason Works, *Foundry Dept.*,
Rochester, N. Y.

1908 Globe Foundry Co.,
Port Chester, N. Y.

1898 Goldens Foundry & Machine Co.,
Columbus, Ga.

1908 Goldie & McCollough Co., Ltd., The,
Galt, Ont.

1904 Goldschmidt Thermit Co., The,
90 West St., New York City.

1907 Goodnow Foundry Co., L. H.,
Fitchburg, Mass.

1898 Goulds Manufacturing Co., The,
Seneca Falls, N. Y.

1907 Graceton Coke Co.,
Graceton, Indiana Co., Pa.

1901 Graham, William,
Box 133, Matteawan, N. Y.

1910 Graham Manufacturing Co., James,
San Francisco, Cal.

1910 Grand Rapids Foundry Co.,
Grand Rapids, Wis.

1896 Green Fuel Economizer Co., The,
Matteawan, N. Y.

1908 Gregg Manufacturing Co., The,
Cleveland, O.

1905 Griffin Wheel Co.,
Sacramento Square, Chicago, Ill.

1907 Gulick, W. W., *M. F. Gulick Sand Co.*,
Riverside, Pa.

1907 Gulick, Henderson Co.,
Pittsburgh, Pa.

1901 Hadfield, Sir Robert.
28 Hertford St., Mayfair, London, England.

1910 Hall, J. W.,
Apartado, 198 San Luis Potosi, Mexico.

1908 Hamilton, H. V., *The Steel Co. of Canada, Ltd.*,
Hamilton, Ont.

1909 Hanna & Co., M. A., *Eliot A. Kebler, Res. Agt.*,
Oliver Bldg., Pittsburgh, Pa.

1904 Hanna Engineering Works,
2075 Ellston Ave., Chicago, Ill.

1908 Hanner, Edward
Dubois, Pa.

1904 Harbison-Walker Refractories Co.,
Pittsburgh, Pa.

1907 Harrison Safety Boiler Works,
Philadelphia, Pa.

1906 Hartford Laboratory, The,
Hartford, Conn.

1907 Hartman Foundry Co., H. J.,
Grand Rapids, Mich.

1908 Hauck Mfg. Co.,
Richards St. & Hamilton Ave., Brooklyn, N. Y.

1910 Haven Malleable Castings Co., The,
Cincinnati, O.

1907 Haupt, Clarence E., *Danville Foundry & Machine Co.*,
Danville, Pa.

1909 Hawkins, David S., M. E.
Rose Bldg., Cleveland, O.

1907 Hawley Down Draft Furnace Co.,
Superior & Townsend Sts., Chicago, Ill.

1908 Heath Foundry & Mfg. Co., The,
Plymouth, O.

1910 Hedges Lincoln Iron Works,
644 M. St., Lincoln, Neb.

1908 Hennessy Foundry Co., The,
Springfield, O.

1908 Herendeen Mfg. Co.,
Geneva, N. Y.

1907 Herman Pneumatic Molding Machine Co.,
Zelienople, Pa.

1908 Hersey, Dr. Milton L.,
171 St. James St., Montreal, P. Q.

1902 Hickman, Baylor, *Hickman, Williams & Co.*,
Louisville, Ky.

1907 Hickman, Williams & Co.,
Cincinnati, O.

1910 High Pressure Sand Blast Co.,
20 Broad St., New York City.

1908 Hildreth Mfg. Co., The,
Lansing, Mich.

1897 Hill & Grifith Co., The,
Cincinnati, O.

1907 Hilles & Jones Co., *Foundry Dept.*,
Wilmington, Del.

1908 Hillis & Sons, Ltd.,
Halifax, N. S.

1903 Hillman & Son., J. H.,
Pittsburgh, Pa.

1905 Holland Linseed Oil Co.,
2012 Austin Ave., Chicago, Ill.

1909 HOLMES, LYMAN A.,
Ford Motor Co., Romeo, Mich.

1907 HOMER, J. R.,
Galion, Crawford Co., O.

1905 HOOPER, GEO. K., M. E.,
165 Broadway, N. Y.

1908 HOTT, PETER,
202 East Burgess St., Mount Vernon, O.

1906 HUNT CO., C. W.,
West New Brighton, N. Y.

1907 HUNTER MACHINE CO., JAMES,
North Adams, Mass.

1910 HUNT SPILLER MFG. CO.,
383 Dorchester Ave., So. Boston, Mass.

1908 I'KAWA, Y., Care of Marquis K. Inouye,
Azabu, Tokio, Japan.

1906 ILLINOIS MALLEABLE IRON CO.,
1801 Diversey Boulevard, Chicago, Ill.

1908 INDIANA FOUNDRY CO.,
Indiana, Pa.

1910 INDUSTRIAL WORKS,
Bay City, Mich.

1910 INGERSOLL-RAND CO.,
11 Broadway, New York City.

1910 INTERNATIONAL CORRESPONDENCE SCHOOLS,
Scranton, Pa.

1906 INTERNATIONAL HEATER CO.,
Utica, N. Y.

1905 INTERSTATE FOUNDRY CO., THE,
Cleveland, O.

1910 IOWA MALLEABLE IRON CO.,
Fairfield, Ia.

1899 IRON AGE, THE, *A. M. Findley, Editor*,
14 Park Place, New York City.

1908 IRON CITY SANITARY MFG. CO.,
18 Wood St., Pittsburgh, Pa.

1903 IRON TRADE REVIEW,
Park Bldg., Pittsburgh, Pa.

1910 IRWINE, ARTHUR M., *Parker Foundry Co., Ltd.*,
Montreal, P. Q.

1907 JAMIESON COAL & COKE CO.,
Pittsburgh, Pa.

1909 JANESVILLE MACHINE CO., THE,
Janesville, Wis.

1896 JARECKI MFG. CO.,
Erie, Pa.

1908 JAMES JILES CO., THE,
Pittsburgh, Pa.

JONES, W. A., HON. MEMBER,
North Ave. & Noble St., Chicago, Ill.

1897 JONES FOUNDRY & MACHINE CO., W. A.,
North Ave. & Noble St., Chicago, Ill.

1907 JOSEPH, E. E., *Washington & Perry,*
Buffalo, N. Y.

1904 JUSTICE, D. G. P., *Pittsburgh, Valve Foundry & Cons. Co.,*
Pittsburgh, Pa.

1908 KAWIN CO., CHAS. C.,
11 Colburn St., Toronto, Ont.

1898 KELLY & CO., T. P.,
544 West 22nd St., New York Ci y.

1900 KELLY FOUNDRY & MACHINE CO.,
Goshen, Ind.

1909 KELLOGG CO., M. W., THE,
117 West Side Ave., Jersey City, N. J.

1908 WM. KENNEDY & SONS LTD., THE,
Owen Sound, Ont.

1906 P. KENNEDY'S FOUNDRY & BALT. MALLEABLE & STEEL CASTING CO.,
Baltimore, Md.

1908 KERR, H. O.,
Walkerville, Ont.

1907 KERR MURRAY MFG. CO.,
Ft. Wayne, Ind.

1906 KEWANEE BOILER CO.,
Kewanee, Ill.

1907 KILLING MOLDING MACHINE CO.,
Davenport, Ia.

1910 KIRK, DR. EDWARD,
938 N. 10th St., Philadelphia, Pa.

1909 KIRK, JOHN L.,
Ferguson Bldg., Pittsburgh, Pa.

1896 KITTANNING IRON & STEEL MFG. CO.,
Kittanning, Pa.

1907 KLAUS, W. G., *Best Mfg. Co.*,
Pittsburgh, Pa.

1906 VICTOR KNECHT CO., THE,
819 Wade St., Cincinnati, O.

1907 KNICKERBOCKER, JOHN,
Waterford, N. Y.

1896 KNOEPPEL, JOHN C.,
238 Alice St., Pittsburgh, Pa.

1908 KNOWLTON, C. F., *Westinghouse Electric & Mfg. Co.*,
Allegheny, Pa.

1903 KOHLER SONS CO., J. M.,
Sheboygan, Wis.

1907 KOPPEL ARTHUR CO., THE,
68 Broad St., New York City.

1906 KREUZPOINTNER, P.,
1400 Third Ave., Altoona, Pa.

1908 KROESCHELL BROS. CO.,
55 Erie St., Chicago, Ill

1907 LACONIA CAR CO. WORKS, THE,
Laconia, N. H.

1907 LA CROSSE PLOW CO.,
La Crosse, Wis.

1906 LACY CO., JAS. J.,
1401 Block St., Baltimore, Md.

1908 LAMB KNITTING MACHINE CO.,
Chicopee Falls, Mass.

1907 LANDERS. FRAY & CLARK,
New Britain, Conn.

1900 LANE, H. M.,
10,613 Greenlawn Ave., Cleveland, O.

1896 LANE & BODLEY CO., THE,
Cincinnati, O.

1896 LANE MFG. CO.,
Montpelier, Vt.

1909 LAWRENCE IRON & STEEL FOUNDRY CO.,
Pittsburgh, Pa.

1910 C. A. LAWTON CO., THE,
De Pere, Brown Co., Wis.

1910 LEBANON STEEL CASTING CO.,
Lebanon, Pa.

1896 LEFFEL & CO., THE JAMES,
Springfield, O.

1910 LEIB, E. E.,
179 W. Main St., Battle Creek, Mich.

1908 LEIGHTON, F. W.,
1512 Pitt St., Wilkinsburg, Pa.

1908 LEMON, E. B.,
652 Wentworth Ave., Milwaukee, Wis.

1900 LEUTHNER, FRANK,
56 Richfield Ave., Buffalo, N. Y.

1900 LEWIS FOUNDRY & MACHINE CO.,
Box 1597, Pittsburgh, Pa.

1908 LEWIS INSTITUTE,
Chicago, Ill.

1905 LIDGERWOOD MFG. CO.,
96 Liberty St., New York City.

1896 LINCOLN & CO., GEO. H.,
South Boston, Mass.

1900 LINDEMANN & HOVERSON CO., A. J.,
Milwaukee, Wis.

1907 LINDSAY & CO., W. W.,
Harrison Bldg., Philadelphia, Pa.

1908 LITTLE, INC., ARTHUR D.,
93 Broad St., Boston, Mass.

1910 LITTLE, J. W.,
9 Penn St., Waynesboro, Pa.

1896 LOBDELL CAR WHEEL CO,
Wilmington, Del.

1909 LODGE & SHIPLEY MACHINE TOOL CO.,
Cincinnati, O.

1906 LODGE MFG. CO.,
South Pittsburgh, Pa.

1907 LOGAN, JOHN A., *Jones & Laughlins Steel Co.*,
Pittsburgh, Pa.

1899 Lombard Iron Works & Supply Co.,
Augusta, Ga.

1908 Long Mfg. Co. Ltd., The E.,
Orillia, Ont.

1910 Lord & Burnham Co.,
Irvington, N. Y.

1910 Lorenz, Wm. A.,
60 Prospect St., Hartford, Conn.

1902 Loudon, Archie M.,
455 Spaulding St., Elmira, N. Y.

1909 Lufkin Foundry & Machine Co.,
Lufkin, Texas.

1909 Lynchburg Foundry Co.,
Lynchburg, Va.

1907 MacKinnon Boiler & Machine Co.,
Bay City, Mich.

1907 Madison Foundry Co., The,
Cleveland, O.

1896 Magee Furnace Co.,
Chelsea, Mass.

1908 Ma Girl, P. H.,
Bloomington, Ill.

1896 Maher & Flockhart,
60 Polk St., Newark, N. J.

1896 Malleable Iron Fittings Co.,
Branford, Conn.

1906 MANUFACTURERS FOUNDRY CO., THE,
Waterbury, Conn.

1903 MARSHALL, S B., Res. Agt., *L. K. Wister & Co.*,
Pittsburgh, Pa.

1903 MARSHALL FOUNDRY CO.,
Pittsburgh, Pa.

1905 MASON, O. M., *Midland Steel Co.*,
Pittsburgh, Pa.

1908 MASSEY-HARRIS CO. LTD.,
915 King St. W., Toronto, Ont.

1907 MATTICE, A. M., *Walworth Mfg Co.*,
S. Boston, Mass.

1909 MAYSVILLE FOUNDRY & ENG. CO.,
Maysville, Ky.

1908 MCCLARY MFG. CO., THE,
London, Ont.

1900 MCCONE, ALEX. J., *Nevada Engineering Works*,
Reno, Nev.

1896 MCCORMICK CO., J. S.,
Pittsburgh, Pa.

1907 MCCRUM-HOWELL CO., THE,
103 Park Ave., New York City.

1908 R. MCDOUGALL CO. LTD., THE,
Galt, Ont.

MCFADDEN, W. H;. HON. MEMBER
Pittsburgh, Pa.

1898 McIntosh, Seymour & Co.,
Auburn, N. Y.

1909 McKay, John A.,
Dunn, N. C.

1900 McKeefrey & Co.,
Leetonia, O.

1907 McKinney, W. C., *Dawes & Miler Works*,
New Brighton, Pa.

1898 McLagon Foundry Co., The,
New Haven, Conn.

1909 J. H. McLain Co., The,
Canton, O.

1904 McLean, E.,
Altoona, Pa.

1909 McLeod & Co., Walter,
Cincinnati, O.

1908 McMichael, P., *The Dominion Radiator Co.*,
Toronto, Ont.

1907 McNab & Harlin Mfg. Co.,
Paterson, N. J.

1901 Medart Patent Pulley Co.,
St. Louis, Mo.

1907 Meeker Foundry Co.,
95 Clay St., Newark, N. J.

1903 Mesta Machine Co.,
P. O. Box 1124, Pittsburgh, Pa.

1907 Metric Metal Works,
P. O. Box 710, Erie, Pa.

1909 Miami Foundry Co.,
Hamilton, O.

1910 Michigan Motor Castings Co.,
Flint, Mich.

1910 Michigan Steel Castings Co.,
Detroit, Mich.

1896 Michigan Stove Co.,
Detroit, Mich.

1908 Midland Engine Works Co.,
Midland, Ont.

1907 Milford Iron Foundry,
Milford, Mass.

1907 Miller, C. M., *The Superior Foundry Co.*,
Cleveland, O.

1904 Millers Products Co., *W. J. Brant*, Sales Agt.,
Pittsburgh, Pa.

1905 Mills Mfg. Co., The H. E.,
Syracuse, N. Y.

1907 Mitchell, R. R., *The Robt. Mitchell Co. Ltd.*,
Montreal, P. Q.

1907 Modern Foundry Co., The,
Oakley, O.

1907 Moffat, J., K.,.
Weston, Ont

MOLDENKE, DR. RICHARD, Hon. Member,
Watchung, N. J.

1907 MOLDER, H. M., *The Best Foundry Co.*,
Bedford, O.

1910 MOLINE FOUNDRY CO., THE,
Moline, Ill.

1907 MOLINE PLOW CO.,
Moline, Ill.

1907 MONARCH ENGINEERING CO., THE,
7 West Lombard St., Baltimore, Md.

1905 MONESSEN FOUNDRY & MACHINE CO
Monessen, Pa.

1909 MONITOR STOVE & RANGE CO., THE,
Cincinnati, O.

1910 MONROE FURNACE & FOUNDRY CO.,
Monroe, Mich.

1909 MONTREAL STEEL WORKS, LTD.,
Montreal, P. Q.

1908 MOODY & SONS CO., THE M.,
Terrebonne, P. Q.

1910 MOONEY, J. F.,
325 West 6th St., Columbus, O.

1908 MOORE, JOHN W., *Warren Foundry & Machine Co.*,
Phillipsburg, N. J.

1909 MOORE & SONS, SAMUEL L., CORP.,
Elizabeth, N. J.

1896 Moore Bros. Co.,
Joliet, Ill.

1907 Moran, James,
414 Arcade Bldg., Philadelphia, Pa.

1910 Morgan Engineering Co.,
Alliance, O.

1907 Morris Foundry Co., The John B.,
Court, Harriet & Vogt Sts., Cincinnati, O.

1896 Mott Co., J. L.,
Trenton, N. J.

1910 Mountain City Stove & Mfg. Co.,
Chattanooga, Tenn.

1904 Mount Carbon Co., The,
Powellton, W. Va.

1907 Mudge & Co., E. W.,
Pittsburgh, Pa.

1907 Mueller, Philip,
Decatur, Ill.

1906 Mullen, John,
516 No. Franklin St., Shamokin, Pa.

1906 Mumford Molding Machine Co.,
30 Church St., New York City.

1910 Munnoch, P, *American Brake Shoe & Fdry Co.,*
Mahwah, N. J.

1902 Murphy, Jas. A., *Hoover, Owens & Rentschler Co.,*
Hamilton, O.

1908 Murphy, M. F., *American Locomotive Works*,
Schenectady, N. Y.

1907 Murphy Iron Works,
Detroit, Mich.

1907 Myrick Machine Co.,
Olean, N. Y.

1901 National Car Wheel Co.,
Pittsburgh, Pa.

1909 National Core Oil Co.,
Corning, N. Y.

1901 National Gear Wheel Foundry,
Pittsburgh, Pa., N. S.

1909 National Roll & Foundry Co.,
Avonmore, Pa.

1906 National Sewing Machine Co.,
Belvidere, Ill.

1910 National Supply Co., The,
Station "B", Toledo, O.

1900 National Tube Co.,
Kewanee, Ill.

1908 Nelson Valve Co., The,
Chestnut Hill, Philadelphia, Pa.

1907 Newberry Mfg. Co.,
Monroe, N. Y.

1907 Newbury, Jay Herbert,
Goshen, N. Y.

1896 NEW ENGLAND BUTT CO.,
Providence, R. I.

1909 NEWPORT SAND BANK CO.,
Newport, Ky.

1898 NEW YORK AIR BRAKE CO., THE,
Watertown, N. Y.

1906 NILES-BEMENT-POND CO.,
Philadelphia, Pa.

1897 NILES TOOL WORKS CO., THE,
Hamilton, O.

1907 NORTH & JUDD MFG. CO.,
New Britain, Conn.

1907 NORTHERN ENGINEERING WORKS,
Detroit, Mich.

1910 NOYE MFG. CO.,
Buffalo, N. Y.

1909 NUTE FOUNDRY CO., THE,
Cuyahoga Falls, O.

1909 OBERHELMAN FOUNDRY CO., J. A.,
Cincinnati, O.

1907 OBER MANUFACTURING CO.,
Chagrin Falls, O.

1896 OBERMAYER CO., THE S.,
Cincinnati, O.

1900 O'DOWD, H. W., *W. M. Crane Co.*,
Jersey City, N. J.

1907 OHIO FOUNDRY CO.,
Steubenville, O.

1907 OHIO MALLEABLE IRON CO., THE,
Columbus, O.

1910 OHIO SAND CO.,
Conneaut, O.

1909 OIL WELL SUPPLY CO.,
Oil City, Pa.

1905 OLIVER MACHINERY CO.,
Grand Rapids, Mich.

1908 OLSEN, C. O., *The Johnson & Jennings Co.*,
Cleveland, O.

1910 ONTARIO MALLEABLE IRON CO. LTD., THE,
Oshawa, Ont.

1908 ONTARIO WIND ENGINE & PUMP CO.,
Toronto, Ont.

1899 ORMROD, JOHN D.,
Emaus, Pa.

1907 OSBORN MFG. CO., THE,
Cleveland, O.

1908 OWEN SOUND IRON WORKS CO. LTD., THE,
Owen Sound, Ont.

1907 PALMERS & DE MOOY FOUNDRY CO., THE,
Cleveland, O.

1905 PANGBORN CO., THOS. W.,
90 West St., New York City.

1909 PARKER BROS. CO. LTD.,
Detroit, Mich.

1902 PARRY, WM. H.,
664 E. 31st St., Brooklyn, N. Y.

1909 PATCH, INC., A. H.,
Clarksville, Tenn.

1898 PATTIN BROS. CO., THE,
Marietta, O.

1896 PAXSON CO., J. W.,
Pier 45, Philadelphia, Pa.

1908 PAYNE, D. W.,
502 Baldwin St., Elmira, N. Y.

1908 PEASE FOUNDRY CO., LTD.,
Toronto, Ont.

1902 PECK & CO., FRANCIS J.,
Cleveland, O.

1907 PENN CASTING & MACHINE CO.,
Pittsburgh, Pa., N. S.

1908 PENNSYLVANIA STEEL CO., THE,
Steelton, Pa.

1909 PENNY EDGAR, V. P., *Newburg Ice Mach. & Eng. Co.,*
Newburgh, N. Y.

1896 PENTON, JOHN A.,
Penton Bldg., Cleveland, O.

1907 PERRY IRON CO.,
Erie, Pa.

1909 Paterson Co., T. J.,
Chicago, Ill.

1906 Pettinos Bros.,
Bethlehem, Pa.

1909 Philadelphia Chaplet & Mfg. Co.,
Philadelphia, Pa.

1909 Phillips & Buttorf Mfg. Co.,
Nashville, Tenn.

1900 Phillips & McLaren Co.,
Pittsburgh, Pa.

1909 Phillips Mine, Mill & Supply Co.,
Pittsburgh, Pa.

1909 Pickands, Brown & Co.,
Chicago, Ill.

1896 Pickands, Mather & Co.,
Cleveland, O.

1896 Pilling & Crane,
Philadelphia, Pa.

1907 Pilling & Crane,
Pittsburgh, Pa.

1910 Piqua Blower Co., The,
Piqua, O.

1907 Piqua Flour Co., The,
Piqua, O.

1907 Pittsburgh Malleable Co.,
Pittsburgh, Pa.

1910 POCAHONTAS COKE CO.,
Cincinnati, O.

1903 PORTER, DR. JOHN JERMAIN,
3450 Burch St., Cincinnati, O.

1909 PORTLAND STOVE FOUNDRY CO.,
Portland, Me.

1896 POTTER PRINTING PRESS CO.,
Plainfield, N. J.

1902 POUGHKEEPSIE FOUNDRY & MACHINE CO.,
Poughkeepsie, N. Y.

1907 PRATT & CADY,
Hartford, Conn.

1904 PRESSED STEEL CAR CO.,
Pittsburgh, Pa.

1897 PRIDMORE, HENRY E.,
Chicago, Ill.

1906 PULASKI IRON CO.,
Philadelphia, Pa.

1910 QUINCY, MANCHESTER, SARGENT CO.,
Plainfield, N. J.

1906 RATHBONE, SAND & CO.,
Albany, N. Y.

1907 RAYMOND MFG. CO., LTD., THE,
Guelph, Ont.

1908 REASONER, R. B.,
Marshalltown, Ia.

1908 REDINGTON, PATRICK,
79 Perry St., Salem, O.

1910 REED FOUNDRY CO.,
Worcester, Mass.

1906 REEVES & CO. LIC.,
Columbus, Ind.

1909 RICHMOND FOUNDRY & MFG. CO.,
Richmond, Va.

1910 RIVERSIDE IRON WORKS,
Chicago, Ill.

1907 ROBBINS & MYERS CO., THE,
Springfield, O.

1908 ROBERTSON CO. LTD., THE JAMES,
Toronto, Ont.

1907 ROBESON PROCESS CO.,
Au Sable Forks, N. Y.

1909 ROBINSON, LOUIS G.,
Harrison Bldg., Cincinnati, O.

1910 ROCK ISLAND PLOW CO.,
Rock Island, Ill.

1907 ROCKWELL FURNACE CO.,
New York City.

1896 ROGERS, BROWN & CO.,
Cincinnati, O.

1900 ROGERS, BROWN & CO.,
Pittsburgh, Pa.

1904 ROSEDALE FOUNDRY & MACHINE CO.,
North Side, Pittsburgh, Pa.

1907 ROSENSTIEL, W. F.,
Johnstown, Pa.

1898 ROSS-MEEHAN FOUNDRY CO.,
Chattanooga, Tenn.

1907 ROSS, TACONY CRUCIBLE CO.,
Philadelphia, Pa.

1907 ROTHE, JOS. F., *Green Bay Iron & Brass Foundry*,
Green Bay, Wis.

1908 RUMELY CO., M.,
La Porte, Ind.

1908 RUSSELL & CO., THE,
Massillon, O.

1906 RUSSELL & ERWIN MFG. CO.,
New Britain, Conn.

1896 RUSSELL WHEEL & FOUNDRY CO.,
Detroit, Mich.

1896 ST. PAUL FOUNDRY CO.,
St. Paul, Minn.

1909 SAND MIXING MACHINE CO.,
220 Broadway, New York City.

1907 SANDY HILL IRON & BRASS WORKS, THE,
Sandy Hill, N. Y.

1901 SARGENT & CO.,
New Haven, Conn.

1903 SAUNDERS & FRANKLIN,
Box 226, Olneyville Sta., Providence, R. I.

1906 SCHAUM & UHLINGER, INC.,
Philadelphia, Pa.

1909 SCHECKLER, M. O., *Union Switch & Signal Co.*,
Swissvale, Pa.

1910 SCHILL BROS. CO., THE,
Crestline, O.

1910 SCHREIBER, WM. A.,
626 June St., Cincinnati, O.

SCHUMAN, FRANCIS, Hon. Member,
Tacony, Pa.

1908 SCHWARTZ HENRY A.,
522 Tibbs Ave., Indianapolis, Ind.

1909 SCOTT IRON & STEEL CO.,
Carnegie, Pa.

1910 SCRUTARI TRUST,
E. T. Bank Bldg., Montreal, P. Q.

1910 SEAGER ENGINE WORKS,
Lansing, Mich.

SEAMAN, J. S., Hon. Member, *Seaman-Sleeth Co.*,
Pittsburgh, Pa.

1896 SEAMAN SLEETH CO., THE,
Pittsburgh, Pa.

1905 SEARS, WM. T., *Bement, Miles & Co.*,
Philadelphia, Pa.

1906 SELLERS & CO., INC., WM.,
Philadelphia, Pa.

1907 SHARPSBURG FOUNDRY CO.,
Sharpsburg, Pa.

1908 SHELDEN'S, LTD.,
Galt, Ont.

1907 SHENANGO MACHINE CO.,
Sharon, Pa.

1896 SHEPPARD & CO., ISAAC A.,
Philadelphia, Pa.

1900 SHERIFFS MFG. CO.,
Milwaukee, Wis.

1909 SHIRLEY, LOYD E.,
5936 Normal Blvd., Chicago, Ill.

1905 SILL STOVE WORKS,
Rochester, N. Y.

1900 SIMMONDS MFG. CO., THE,
Kenosha, Wis.

1899 SLY MFG. CO., THE W. W.,
Cleveland, O.

1909 SMART, R. A., *Oliver Chilled Plow Co.*,
South Bend, Ind.

1909 SMITH, EUGENE W.,
17 N. Franklin Ave., Chicago, Ill.

1902 SMITH & ANTHONY CO.,
Boston, Mass.

1908 SMITH CO., THE H. B.,
Westfield, Mass.

1897 SMITH'S FALLS MALLEABLE CASTING CO., LTD.,
Smith's Falls, Ont.

1896 SMITH FOUNDRY SUPPLY CO., THE J. D.,
Cleveland, O.

1910 SNYDER, FREDERICK T.,
Monadnock Bldg., Chicago, Ill.

1899 SOUTHER, HENRY,
Hartford, Conn.

1909 SOUTHWESTERN IRON CO., THE,
Guthrie, Okla.

1896 SPRINGFIELD FACING CO.,
Springfield, Mass.

1909 SQUIER CO., ED. E.,
St. Louis, Mo.

1910 STACKS, DON H., *Deere & Co.*,
Moline, Ill.

1910 STANDARD FOUNDRY CO.,
Detroit, Mich.

1906 STANDARD IDEAL CO., LTD., THE,
Port Hope, Ont.

1907 STANDARD MALLEABLE IRON CO.,
Muskegon, Mich.

1910 STANDARD PATTERN WORKS.,
144 First St., E., Detroit, Mich.

1907 STANDARD SAND & MACHINE CO.,
Cleveland, O.

1907 STANDARD SANITARY MFG. CO.,
Pittsburgh, Pa.

1902 STEAD J. E.,
Queen's Terrace, Middleborough, England.

1902 STEINWAY & SONS, *Riker Ave. Plant*,
Steinway, L. I., N. Y.

1909 STIRLING WHEELBARROW CO.,
Milwaukee, Wis.

1900 STERRIT-THOMAS FOUNDRY CO.,
Pittsburgh, Pa.

1908 STEVENS, FREDERICK B.,
Detroit, Mich.

1909 STEVENSON CO., THE,
Wellsville, O.

1907 STEWART IRON CO., LTD.,
Sharon, Pa.

1908 STEWART, CHAS. E., *The Jas. Stewart Mfg. Co., Ltd.*,
Woodstock, Ont.

1905 STILLMAN, PROF. THOS. B., *Stevens Inst. Technology*,
Hoboken, N. J.

1909 STOUGHTON, BRADLEY,
165 Broadway, N. Y. City.

1906 STRAIGHT LINE ENGINE CO., THE,
Syracuse, N. Y.

1896 STURTEVANT CO., B. F.,
Hyde Park, Mass.

1905 STUVER, F. J.,
28th & Smallman Sts., Pittsburgh, Pa.

1907 SULLIVAN MACHINERY CO.,
Claremont, N. H.

1909 SWEET & DOYLE FOUNDRY & MACHINE CO.,
Green Island, N. Y.

1908 SWEET IRON WORKS, A. L.,
Medina, N. Y.

1906 SYMINGTON CO., THE T. H.,
Rochester, N. Y.

1896 SYRACUSE PLOW CO.,
Syracuse, N. Y.

1896 TABOR MFG. CO., THE,
Philadelphia, Pa.

1906 TARRANT FOUNDRY CO.,
369 West Indiana St., Chicago, Ill.

1908 TAYLOR & CO.,
Morgan & Norman Aves., Brooklyn, N. Y.

1907 TAYLOR & FENN CO., THE,
Hartford, Conn.

1908 TAYLOR CO., W. P.,
Buffalo, N. Y.

1907 TAYLOR-FORBES CO., LTD.,
Guelph, Ont.

1896 TAYLOR-WILSON MFG. CO.,
McKees Rocks, Pa.

1898 TENNESSEE COAL, IRON & R. R. CO.,
Birmingham, Ala.

1907 TITTLE, C. L.,
Blairsville, Pa.

1907 TOD CO., THE WM.,
Youngstown, O.

1900 TOUCEDA, ENRIQUE,
Albany, N. Y.

1899 TRABUE, W. D.,
First & Monroe Sts., Nashville, Tenn.

TURNER, THOMAS, PROF., Hon. Member, *The University*,
Birmingham, England.

1905 TURNER & SEYMOUR MFG. CO.,
Torrington, Conn.

1901 UNION FOUNDRY & MACHINE CO.,
Pittsburgh, Pa., S. S.

1909 Union Foundry Co.,
Anniston, Ala.

1907 UNION MANUFACTURING CO.,
New Britain, Conn.

1910 UNION STEAM PUMP CO.,
Battle Creek, Mich.

1907 UNION STEEL CASTING CO.,
Pittsburgh, Pa.

1896 Union Stove Works, The,
Peekskill, N. Y.

1906 Union Typewriter Co.,
Ilion, N. Y.

1896 United Foundry & Engineering Co.,
Pittsburgh, Pa.

1896 United Foundry & Engine Co., *Lloyd Booth Dept.*,
Youngstown, O.

1907 United Iron Works Co.,
Springfield, Mo.

1909 U. S. Cast Iron Pipe & Foundry Co.,
Bessemer, Ala.

1906 U. S. Graphite Co.,
Saginaw, Mich.

1910 U. S. Radiator Corporation,
Detroit, Mich.

1906 U. S. Sanitary Mfg. Co.,
Monaca, Pa.

1907 Universal Caster & Foundry Co.,
Newark, N. J.

1906 Utica Heater Co.,
Utica, N. Y.

1908 Utica Pipe Foundry Co.,
Utica, N. Y.

1907 Valentine, C. W.,
137 Mullin St., Watertown, N. Y.

1908 VANCOUVER ENGINEERING WORKS, LTD.,
Vancouver, B. C.

1907 VANDERMAN MFG. CO., THE,
Willimantic, Conn.

1908 VERITY PLOW CO., LTD.,
Brantford, Ont.

1903 VIRGINIA IRON & COKE CO.,
Bristol, Va.-Tenn.

1909 VULCAN IRON WORKS,
Wilkes-Barre, Pa.

WALKER, A. W., Hon. Member, *Walker & Pratt Mfg. Co.*,
Boston, Mass.

1904 WALKER, ROBERT A.,
1202 Park Bldg., Pittsburgh, Pa.

1896 WALKER & PRATT MFG. CO.,
Boston, Mass.

1907 WALKER FOUNDRY CO.,
Erie, Pa.

1909 WALLINGFORD, WALTER & CO.,
Pittsburgh, Pa.

1907 WALWORTH MFG. CO.,
132 Federal St., Boston, Mass.

1910 WARDEN, KING, LTD.,
Montreal, P. Q.

1900 WARWICK IRON & STEEL CO.,
Pottstown, Pa.

1896 Washington Coal & Coke Co.,
Pittsburgh, Pa.

1910 Waterbury Casting Co.,
Waterbury, Conn.

1908 Watrous, C. E., *Watrous Engine Co.*,
Brantford, Ont.

1909 Watson, C. H., *Brass Foundry & Mach. Co.*,
Lenoir, Tenn.

1903 Watts, George W., *Canada Foundry Co.*,
Toronto, Ont.

1908 Watson Mfg. Co., John,
Ayr, Ont.

1910 Webb, Jas. F.,
Davenport, Ia.

1909 Webster Mfg. Co., The,
Tiffin, O.

1908 Wells, A. E., *Cornell University*,
Ithaca, N. Y.

1907 Welsh, E. C., *N. & W. Shops*,
Roanoke, Va.

West, Thos. D., Hon. Member,
10,511 Pasadena Ave., N. E., Cleveland, O.

1896 Western Foundry Co.,
3634 Kedzie Ave., Chicago, Ill.

1908 Western Foundry Co., Ltd., The,
Wingham, Ont.

1896 WESTINGHOUSE AIR BRAKE CO.,
Pittsburgh, Pa.

1896 WESTINGHOUSE MACHINE CO.,
East Pittsburgh, Pa.

1906 WESTMORELAND IRON CO., LTD.,
Westmoreland, N. Y.

1908 WEST SIDE FOUNDRY CO.,
Troy, N. Y.

1908 WEST STEEL CASTING CO., THE,
Cleveland, O.

1898 WHEELING MOLD & FOUNDRY CO.,
Wheeling, W. Va.

1908 WHITE CO., J. S.,
Pawtucket, R. I.

1896 WHITEHEAD BROS. CO.,
537 West 27th St., New York City.

1907 WHITEHOUSE, J. T., *Deemer Steel Casting Co.*,
New Castle, Pa.

1910 WHITE, WARNER CO.,
Taunton, Mass.

1896 WHITING FOUNDRY EQUIPMENT CO.,
Harvey, Ill.

1896 WHITIN MACHINE CO.,
Whitinsville, Mass.

1902 WIEDERMAN, A., *Gremsdorf, Liegnitz*,
Silesia, Germany.

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